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THE SEPTEMBER SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

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THE SCIENTIFIC MONTHLY

SEPTEMBER, 1933

THE CALAKMUL EXPEDITION[1]

By Dr. SYLVANUS G. MORLEY

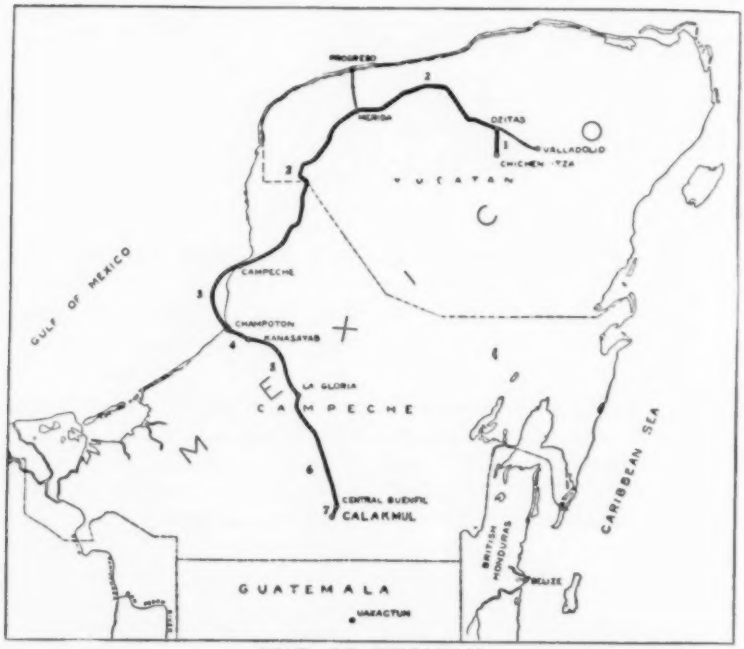
ARCHEOLOGIST OF CARNEGIE INSTITUTION OF WASHINGTON

THE expedition reached Campeche on April 5, where Mr. J. C. Brydon, manager of the Mexican Exploitation Company, met the party. The equipment and supplies had been forwarded to San Dimas, a station on the tram-line between Kanasayab and La Gloria, several days in advance. Mr. Brydon had also engaged two automobiles to take the party the next lap of the journey to the hacienda of San Dimas, 55 miles distant. After an eight-hour drive, the latter part over an all but impassable wood road through the forest, the expedition reached San Dimas at eleven o'clock the same night, where it was most hospitably received by Mr. Sanchez, local manager of the Montana Company, and quartered at the hacienda house.

The next lap of the journey was made over a Decauville tram on small platform cars, ten feet long, drawn by two mules tandem without reins, the mules being attached to the platform by a single pair of traces. At four o'clock on the afternoon of April 6, the expedition reached La Gloria, the chicle station of Don Francisco Buenfil.

Don Francisco Buenfil, of Merida and Campeche, is the largest private chicle operator in the state of Campeche. He had visited Chichen Itzá earlier in the 1932 season and when he learned of the Institution's contemplated expedition to Calakmul had generously placed the facilities of his organization at its service. Occasion should be taken here to state that the success of the Calakmul expedition was due in large measure to the generous assistance received from

[1] Dr. Sylvanus G. Morley, archeologist in charge of the field work in Yucatan for Carnegie Institution of Washington, headed an expedition, which was sent into an uninhabited part of southern Campeche for the purpose of examining the ruins of an ancient Maya city, discovered a few months before by Mr. C. L. Lundell, an employee of a chicle company operating in the region. When on a scouting trip for his company, Lundell, on December 29, 1931, came upon jungle-covered ruins to which he gave the name "Calakmul," which means, in the Maya tongue, "two adjoining mounds," a name having significance, as Lundell thought, because the two highest pyramids, each about 150 feet in height, stood close together. Lundell took photographs and made a sketch map of the site. A little later, these came into the hands of Dr. Morley, who identified the ruins as being those of an Old Empire City which had been built to the north of the known limits of the Old Empire region. Because of its location so far north, Morley believed the ruins to be of sufficient scientific importance to justify the organization of an expedition to visit it and to make a thorough study of its principal features. Obtaining approval of his plan from the Mexican government and from Carnegie Institution, the expedition left field headquarters at Chichen Itzá, Yucatan, Mexico, on April 3, 1932. Its personnel consisted of Dr. Morley, director, Karl Ruppert, archeologist, J. S. Bolles, architect and surveyor, Gustav Stromsvik, engineer, Mrs. Morley, in charge of the commissary, and two camp assistants. Dr. Morley here gives an account of the journey and of the results obtained.



MAP OF YUCATAN

SHOWING LOCATION OF NEWLY DISCOVERED CITY OF CALAKMUL, SOUTHERN CAMPECHE, MEXICO. HEAVY BLACK LINE INDICATES ROUTE FOLLOWED BY CARNEGIE INSTITUTION OF WASHINGTON EXPEDITION FROM CHICHEN ITZÁ TO CALAKMUL.

the members of Mr. Buenfil's efficient organization at all stopping places from Campeche to Calakmul.

The journey beyond La Gloria was made in a five-ton truck over chicle trails that are utterly impassable for motor transport during the rainy season, and not much better during the dry season. The stretch from La Gloria to Central Buenfil, a distance of 70 miles, was covered in 27 consecutive hours, including eight hours out for sleep in the midst of the forest.

The expedition left La Gloria at 3:15 on the afternoon of April 7 and reached Central Buenfil at 6:15 the following afternoon, after a nerve-racking, muscle-beating journey. The truck-pass over the hills was narrow, the truck scraping the bushes and trees on either side and breaking off the lower branches as it lumbered along.

In the *akalches*, or swamps, the lower bush is cleared to a width of about 100 feet so that the sun may reach these marshy places. Although these marshes were nearly dry at the time the expedition passed through them, several bogs were traversed which necessitated chaining short logs to the rear wheels to provide sufficient traction in the bottomless mud.

The expedition was cordially received at Central Buenfil by Don Manuel Osorno, the general manager, and arrangements were made with him for mules to transport the party and outfit the remaining seven miles south to the ruins of Calakmul.

Thirty mules, including pack animals, were required to transport the personnel and outfit from Central Buenfil to Calakmul. Fifteen laborers were employed during the fifteen days' stay at

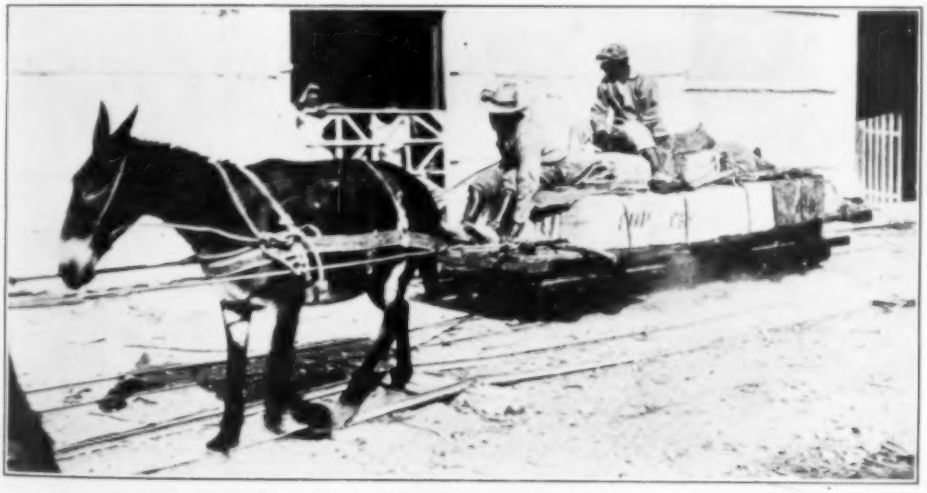
the site (April 9–24) and two camp cooks.

The first afternoon (April 9) was devoted to making camp, putting up tent covers for sleeping quarters and mess hall, building a kitchen stove and table, and arranging the outfit, supplies, saddles, tools, etc.

The following day was one of the most remarkable in the writer's twenty-five years of tropical exploration. With the Lundell sketch map as a guide, the institution party set out to explore the area covered by the map. Lundell had enumerated 64 stelae, or sculptured hieroglyphic monuments, of which the expedition was able to find all but two. One of the missing two was the unsculptured rectangular altar on the summit of the substructure supporting the middle building of Structure D, which Lundell had mistaken for a sculptured stela; the other was not found in the position indicated on his sketch map and it appears probable that he must have confused it with some other stela already accounted for elsewhere. This reduced the total of stelae found by Lundell to 62.

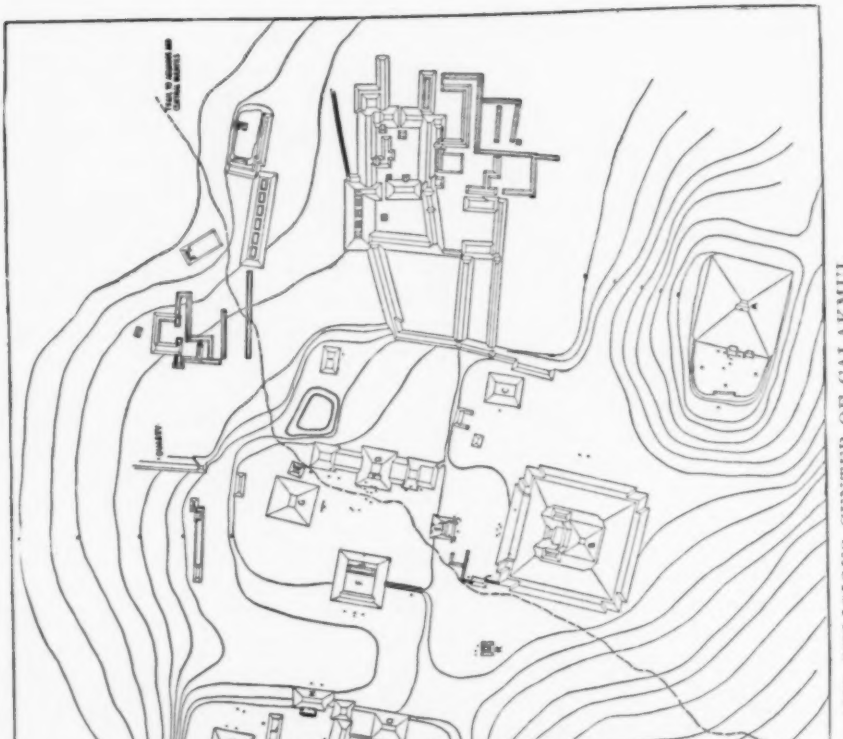
The Carnegie Institution's Calakmul expedition, during the 15 days it was at the site, discovered 41 additional stelae, bringing the total of known stelae at this site to 103, the largest number by 27 per cent. yet reported from any other city of the Maya civilization. The nearest competitor to Calakmul in this respect is Tikal in northern Guatemala, which contains a total of 75 stelae, of which, however, only 18 (*i.e.*, less than 25 per cent.) are sculptured. The Old Empire site having the largest number of sculptured stelae previously reported is Piedras Negras in northeastern Guatemala with a total of 45.

Calakmul, on the other hand, has at least 74 surely sculptured stelae, and of the remaining 29 it is practically certain that another half dozen originally had been sculptured, although their carving has entirely disappeared owing to the softness of the limestone which was used and the excessive weathering to which the stelae have been subjected. It is therefore hardly an exaggeration to say that originally Calakmul probably had almost twice as many sculptured



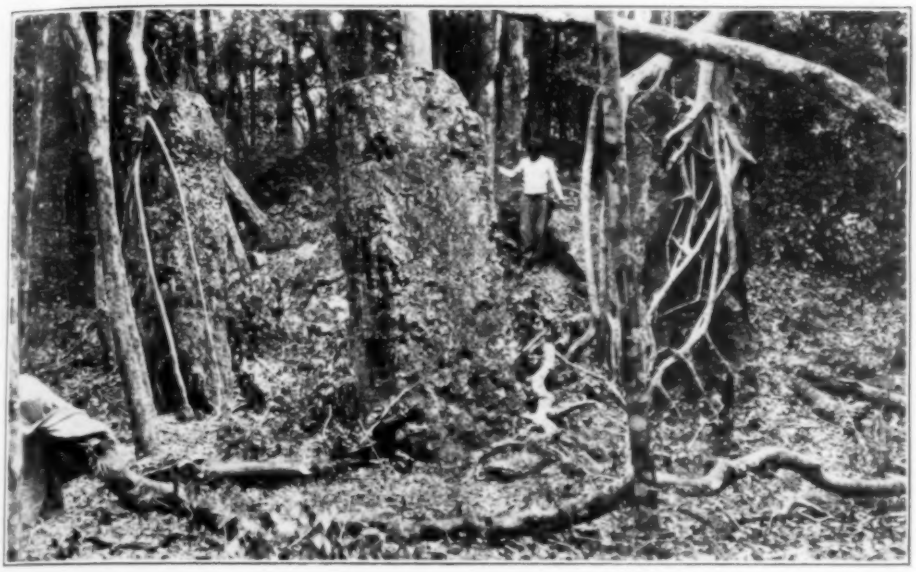
PLATFORM CAR DRAWN BY TWO MULES, TANDEM

USED IN HAULING OUT BLOCKS OF CHICLE (CRUDE CHEWING GUM) FROM THE INTERIOR. THE CALAKMUL EXPEDITION PERSONNEL AND BAGGAGE TRAVELED FOR FIFTY MILES ON THESE PLATFORM CARS.



MAP OF THE CIVIC AND RELIGIOUS CENTER OF CALAKMUL

SURVEYED AND DRAWN BY MR. J. S. BOLLES. THE PRINCIPAL STRUCTURES ARE DESIGNATED BY LETTERS; THE MONUMENTS ARE REPRESENTED BY SMALL BLACK RECTANGLES. NOTE THAT THE AREA BOUNDED BY STRUCTURES D, E, F, G, CONSTITUTES THE MAIN PLAZA OF THE CITY. IT WAS HERE THAT THE STAFF CAMP WAS ESTABLISHED.



THREE SCULPTURED STELAE

AT SOUTHWESTERN CORNER OF STRUCTURE E. THE MONUMENT AT THE RIGHT HAS A WILD FIG TREE GROWING ON TOP OF IT, THE ROOTS COVERING THE FRONT.

stelae as any other Maya site yet discovered.

The work of the expedition was divided as follows: The writer devoted his time to the epigraphy, assisted by Mr. Stromsvik who took entire charge of turning the heavy fallen monoliths, some weighing as much as five or six tons, many laying with their sculptured faces downward. Mrs. Morley took charge of the photography; Mr. Ruppert made a study of the architecture, though only one building, Structure C, was sufficiently preserved to allow a detailed ground-plan to be made of it without excavation. Mr. Bolles made a surveyed map of the center of the site, covering an area about three fifths of a mile long by about half a mile wide, and located the positions of all mounds and monuments thereupon. Bolles also determined the latitude of Calakmul as 18° 2′ N. and the longitude as about 89° 52′ W. Finally, in addition to his work in turning the fallen stelae, Mr. Stromsvik made a number of minor excavations looking for stratified deposits of potsherds; he also made a study of the small stone artifacts which were found, such as *metates*,[2] grinders, etc.

One of the most important results of the expedition was the discovery of no less than 51 Initial Series, the largest number of these amazingly accurate time-counts or dates ever found at any other Old Empire city except Copan in Honduras. Of this number it was possible to decipher the dates of 42, surely; of two more, probably; and of nine, more doubtfully. In addition to these 51 Initial Series, four Period-Ending dates were identified. In all, the dates of about half of the 103 stelae found at Calakmul may be said to have been correctly deciphered.

The dates of the Calakmul stelae, in so far as they have been deciphered, ar-

[2] The name generally applied to the stone slabs or blocks upon which the American Indian grinds his corn.

LIST OF DATES DECIPHERED AT CALAKMUL

Monument	Date in Maya Chronology[1]	Date in Christian Chronology[2]	Kind of Date
Stela 43	9. 4. 0. 0. 0	254 A.D.	Initial Series
" 28	9. 9.10. 0. 0	364 "	" "
" 29	9. 9.10. 0. 0	364 "	" "
" 1	9.10. 0. ?. 5	373 "	" "
" 9	9.10.16.16.19	390 "	" "
" 32	9.11. 5. 0. 0(??)	398 "	" "
" 33	9.11. 5. 0. 0(?)	398 "	" "
" 35	9.11. 8.10. 8	402 "	" "
" 35[3]	9.11.10. 0. 0	403 "	" "
" 36	9.11.10. 0. 0	403 "	" "
" 9	9.11.10. 0. 0	403 "	" "
" 94	9.12. 0. 0. 0	412 "	Period-Ending
" 13	9.12. 0. 0. 0	412 "	Initial Series
" 74	9.12. 0. 0. 0(??)	412 "	" "
" 75	9.12. 0. 0. 0	412 "	" "
" 86	9.12. 0. 0. 0	412 "	" "
" 76	9.12. 5. 0. 0	418 "	" "
" 70	9.12. 8. 9. 9	421 "	" "
" 77	9.12.10. 0. 0(?)	423 "	" "
" 93	9.12.10. 0. 0	423 "	" "
" 94	9.12.10. 0. 0	423 "	" "
" 79	9.13. 0. 0. 0(??)	432 "	" "
" 23	9.13.10. 0. 0	442 "	" "
" 24	9.13.10. 0. 0	442 "	" "
" 38	9.13.10. 0. 0(??)	442 "	" "
" 40	9.13.10. 0. 0	442 "	" "
" 41	9.13.10. 0. 0(??)	442 "	" "
" 71	9.14. 0. 0. 0	452 "	" "
" 72	9.14. 0. 0. 0	452 "	" "
" 73	9.14. 0. 0. 0	452 "	" "
" 8	9.14.10. 0. 0	462 "	" "
" 46	9.14. ?. ?. ?	462 " / 471 "	" "
" 51	9.14.19. 5. 0	471 "	" "
" 52	9.15. 0. 0. 0	471 "	" "
" 53	9.15. 0. 0. 0	471 "	Period-Ending
" 54	9.15. 0. 0. 0	471 "	Initial Series
" 55	9.15. 0. 0. 0	471 "	" "
" 48	9.15. 0. 0. 0	471 "	" "
" 89	9.15. 0. 0.14	471 "	" "
" 26	9.15. 5. 0. 0	477 "	" "
" 25	9.15.10. 0. 0	482 "	" "
" 27	9.15.10. 0. 0	482 "	" "
" 59	9.15.10. 0. 0	482 "	" "
" 60	9.15.10. 0. 0(??)	482 "	" "
" 62	9.16. 0. 0. 0	491 "	Period-Ending
" 57	9.17. 0. 0. 0	511 "	Initial Series
" 58	9.17. 0. 0. 0	511 "	" "
" 80	9.18. 0. 0. 0	530 "	" "
" 67	9.18.10. 0. 0	541 "	" "
" 69	9.18.10. 0. 0	541 "	" "
" 15	9.19. 0. 0. 0	550 "	Period-Ending
" 16	9.19. 0. 0. 0	550 "	Initial Series
" 64	9.19. 0. 0. 0(??)	550 "	" "
" 39	9. ?. ?. ?. ?	..... "	" "
" 45	9. ?.10. 0. 0	..... "	" "

STELAE 28 AND 29, THE TWO OLDEST MONUMENTS AT CALAKMUL

THEY STAND ON THE NORTH SIDE OF STRUCTURE E AND WERE BOTH ERECTED ON THE SAME DAY, 9.9.10.0.0 IN THE MAYA CHRONOLOGY, WHICH CORRESPONDS TO 364 A.D. IN THE CHRISTIAN CHRONOLOGY, ACCORDING TO THE MORLEY-SPINDEN CORRELATION.

ranged in their chronological order, are given in the accompanying table; the name of the monument appears in the first column; the corresponding date in Maya chronology, in the second column; the corresponding equivalent in Christian chronology, according to the Morley-Spinden correlation, in the third column;[3] and the kind of date, *i.e.*, whether an Initial Series or a Period-Ending, in the fourth column. The corresponding terminal dates of these Initial Series and Period-Ending dates have been omitted for convenience in comparison. Doubtfully deciphered dates are marked with a single interrogation point and very doubtfully deciphered dates with two interrogation points.

In the light of its sculptured monuments Calakmul stands revealed to us as a large, somewhat provincial city of Class 2, which reached the point of erecting sculptured stone monuments at the close of the Early Period (9.9.10.0.0) (see accompanying photograph) and continued the practise until toward the close of the Great Period (9.19.0.0.0) at which time this site seems to have been abandoned, or at least a stage in its social, governmental and economic disorganization had been reached when it

[3] According to the Goodman-Martinez-Thompson correlation of Maya and Christian chronology the dates in the third column are 259 years later.

[1] As noted in the text, 9.4.0.0.0 probably is not the contemporaneous date of Stela 43 but a date perhaps as much as two centuries later.

[2] Morley-Spinden Correlation.

[3] Stela 35 has two Initial Series, though only the second, 9.11.10.0.0, records the contemporaneous date of this monument.

[4] Although Stela 9 has two Initial Series, the contemporaneous date of this monument is recorded by a Period-Ending date, 9.12.0.0.0.

THE MOST BEAUTIFUL MONUMENT AT CALAKMUL

IT IS LOCATED IN FRONT OF THE PYRAMID SUPPORTING STRUCTURE A. THIS STELA (STELA 51) BEARS A DATE WHICH CORRESPONDS TO 471 A.D., ACCORDING TO THE MORLEY-SPINDEN CORRELATION. WHEN DISCOVERED IT WAS LYING WITH ITS SCULPTURED FACE TO THE GROUND WHICH ACCOUNTS FOR ITS EXCELLENT STATE OF PRESERVATION.

was no longer able to erect stone monuments of any kind, either sculptured or unsculptured.

The dates on the Calakmul stelae indicate that the inhabitants of this ancient city marked the ends of the successive five-year periods of the Long Count —the *hotuns*—not only by the erection of a single sculptured monument, as was usually the case, but occasionally, particularly on the *lahuntun* and *katun*-endings (*i.e.*, the ends of the 10- and 20-year periods successively) by the erection of two, three, four and in one case (9.15.0.0.0) even seven different monuments, one of which, Stela 51, is shown.

No other city of the Old Empire displayed such consistent prodigality in the erection of its period markers as did Calakmul. Occasionally, at other cities, two monuments or even more were erected on the same period-ending, but at Calakmul it is safe to say that practically every *lahuntun* and *katun*-ending between 9.9.10.0.0 and 9.19.10.0.0 was commemorated by the erection of more than one monument.

While the sequence of the *hotun*, or 5-year period markers, is by no means as complete at Calakmul as it is either at Piedras Negras or at Quirigua, the number of stelae found at Calakmul (because several rather than one were regularly erected at the *lahuntun* and *katun* endings) is actually nearly two and a half times as large as the number of stelae found at Piedras Negras and nearly nine times as large as the number found at Quirigua. Provincial as the city seems to have been, judging from the art of its sculptured monuments, when it came to mass production, Calakmul may fairly be said to have surpassed every other city of the Maya civilization now known.

The Initial Series of Stela 43 surely reads 9.4.0.0.0, more than a century earlier than the next earliest date, 9.9.10.0.0, recorded on two different monuments—Stelae 28 and 29. However, the stylistic characteristics of Stela 43 are such as to indicate strongly that it had been executed at a much later date than 9.4.0.0.0, possibly as much as two centuries later. Further, the other dated monuments associated with Structure B, in front of which Stela 43 is located, all date from 9.13.10.0.0 (Stelae 38, 40 and 41), nearly two centuries later than 9.4.0.0.0. Finally, there are a number of Calendar Round dates in the inscription on Stela 43, which, although apparently without connecting

Secondary Series numbers, may be much later than 9.4.0.0.0—perhaps as late as 9.13.10.0.0—any one of which may record the dedicatory date of this monument.

Mr. Bolles found that the two principal mounds, Structures A and B (see map of the city), are about the same height, approximately 150 feet. However, since Structure A is built on somewhat higher ground than Structure B, the latter is in reality the higher as well as very much the larger, covering an area 425 feet square, compared to an area, roughly 250 feet square, covered by Structure A. Structure B also, judging from the dates of the monuments associated with it, is 30 years older than Structure A, having been dedicated in 9.13.10.0.0, whereas the seven stelae associated with Structure A were clearly dedicated on the *katun*-ending, 9.15.0.0.0.

The only building sufficiently preserved to permit the reconstruction of its ground plan is Structure C, of which Mr. Ruppert made a close architectural study and measured ground plan (see accompanying plan). This building is composed of two wings at right angles to the main middle section and it had originally twelve chambers and probably a roof comb.[4]

As Bolles was scouting through the forest with his gang of bush cutters opening the main lines of sight for the base map, he discovered many new monuments not found by Lundell. In fact, most of the 41 new stelae reported by the Calakmul expedition were found by Bolles in his exploration of the site incident to making the survey for the base map.

An interesting discovery was that of a large sculptured outcrop of limestone near the middle of a small plaza just west of the Ball Court. By chance, one of the lines of sight for the survey crossed this outcrop, which was completely covered with fallen leaves and humus soil save for a small section, perhaps three feet in diameter, lying directly in the line of clearing.

One of the workmen happened to notice that a human head of heroic size was carved in profile in deep relief—six inches—on the exposed upper face of

DATE GLYPHS ON STELA 89

A BEAUTIFULLY CARVED MONUMENT, FOUND ON THE SUMMIT OF STRUCTURE A, WHICH BEARS GLYPHS CORRESPONDING TO 471 A.D. OF OUR CHRONOLOGY.

[4] The roof-comb in Maya architecture, as its name implies, is a superstructure built on the roof of Maya buildings for decorative purposes.

STRUCTURE C, LOOKING NORTH

THIS IS THE ONLY STRUCTURE AT CALAKMUL SUFFICIENTLY PRESERVED TO PERMIT THE RECONSTRUCTION OF ITS GROUND PLAN. ORIGINALLY IT CONSISTED OF TWELVE CHAMBERS ARRANGED IN TWO WINGS AT RIGHT ANGLES TO THE MAIN MIDDLE SECTIONS (SEE GROUND PLAN).

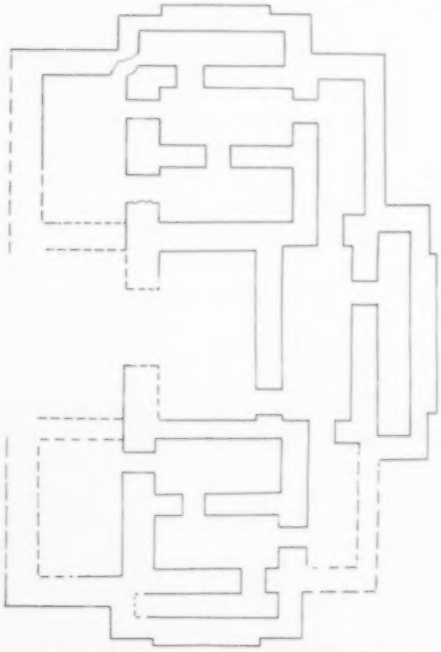
this rock (see illustration). When this outcrop was finally cleared it was found to be an irregular oval, the long axis measuring 21 feet, the short axis, 17 feet.

The entire top of the outcrop was sculptured with six or seven nude human figures, the tallest being nine feet in height; all these had their arms bound behind their backs, the cords showing clearly. There are several glyph-panels scattered over the outcrop but, due to the fact that these had been exposed to a maximum of weathering as well as to the fact that their relief was much lower than that of the captive figures, the interior details of the signs had entirely disappeared.

Other carving on outcrops of living rock in the Maya area of similar character are: the sculptured toad on a projecting ledge of the native andesite on the south side of the Copan Valley in Honduras;[5] the so-called Sacrificial Rock at Piedras Negras, Guatemala;[6] and the stalking jaguar, sculptured on a flat outcrop of limestone at Chichen Itzá, Yucatan, Mexico.[7] Mr. Stromsvik built a platform 17 feet above this sculptured rock at Calakmul, from which the design was photographed by flashlight at night.

Another find, possibly more significant scientifically, was Bolles' discovery of an ancient quarry a short distance north of the Main Plaza. Here two large blocks of stone, which, judging by their size and shape, probably had been intended for use as door lintels, are only partially quarried, one end and one narrow edge of each still remaining fast to the bed of limestone from which they were being worked. While by no means unique, definitely identified quarries at Maya sites are sufficiently rare to merit comment, and the one found this season at Calakmul is perhaps as good an example of this kind yet reported from any Old Empire site.

After turning the fallen monuments, Stromsvik devoted the remainder of his time to minor excavations, chiefly trenching in front of some of the standing stelae, in search of potsherds, of which a surprisingly large number were brought



GROUND PLAN OF STRUCTURE C.

to light. In fact, five ten-gallon gasoline boxes of fragments were brought back to Chichen Itzá, probably the largest collection of potsherds ever obtained from any Old Empire site. In addition to this work, Stromsvik was able to collect parts (sometimes the entire piece) of at least 15 different *metates*.

One of Ruppert's laborers reported having seen, two years before, a group of ruins some 15 to 18 miles by trail

[5] "The Inscriptions at Copan," Carnegie Institution of Washington, Pub. No. 219, by Sylvanus G. Morley, pp. 377, 378.

[6] "Researches in the Central Part of the Usumatsintla Valley," Memoirs Peabody Museum, Harvard University, Vol. II, No. 1, by Theobert Maler, p. 42, and plate VII, No. 1.

[7] Carnegie Institution of Washington Year Book, 1923, p. 216.

SCULPTURED OUTCROP OF NATIVE LIMESTONE

SHOWING THE HEAD OF THE PRINCIPAL FIGURE. AN AREA 17 FEET BY 21 FEET IS COVERED WITH SEVEN CAPTIVE FIGURES REPRESENTED WITH ARMS BOUND BEHIND THEIR BACKS. THE LONGEST OF THESE MEASURES NINE FEET.

northeast of Central Buenfil near the former chicle camp of La Muneca. In addition to the usual mounds, pyramids and fallen structures, now overgrown by the forest, he stated that there were three carved stones like those at Calakmul, two standing and one fallen, with "letters" on them, "letters" being the general designation for hieroglyphics among *chicleros* throughout the Old Empire region. It was obvious that this informant was describing a site where there were at least three sculptured stone monuments.

Messrs. Ruppert and Bolles, having completed their work at Calakmul a day before the other members of the expedition were ready to leave, decided to pay a brief visit to the newly reported site near La Muneca. They left Calakmul on the morning of April 23, reaching Central Buenfil in time for an early lunch, then pushed on to the new site the same afternoon. In the dry season the nearest water to this site is four or five miles away and it was necessary for the party to make a dry camp.

That same afternoon Ruppert, while making a preliminary examination of the ruins, was stricken with his first attack of fever and obliged to take to his hammock. The next morning, with great courage and fortitude, although still suffering from fever, he dragged himself about the ruins until ten o'clock, when he collapsed.

In spite of the very limited time available and Ruppert's serious illness an incredible amount of work was accomplished. In place of the three sculptured monuments reported by the *chiclero*, 23 monuments were found. The site, Bolles reports, is located on two large terraced platforms on either side of a small ravine. He had time to make a sketch map of only the western platform where the 23 stelae are located. A hasty exploration of the eastern platform, however, failed to bring to light any other monuments, though such may nevertheless be there, he believes.

OUTCROP OF NATIVE LIMESTONE

TWENTY-ONE FEET LONG AND 15 FEET WIDE, ON WHICH APPEAR THE SCULPTURED FIGURES OF SIX PRISONERS. A PLATFORM WAS BUILT 17 FEET ABOVE THIS OUTCROP IN ORDER TO PHOTOGRAPH THE FIGURES.

Although neither member of the party is an epigrapher, they were both able to identify, in their very cursory examination of the monuments, at least four Initial Series, of which they deciphered the dates of three:

Stela	4	9.18. 0. 0. 0	530 A.D.
"	3	9.19. 0. 0. 0	550 A.D.
"	16	10. 2. 0. 0. 0	610 A.D.
"	17	?	

The first records the same *katun*-ending as Stela 80 at Calakmul, and the second the same *katun*-ending as Stelae 15, 16 and 64 at Calakmul. Stela 16 at the new site records the date 10.2.0.0.0. This date is (1) 60 years later than the latest date at Calakmul; (2) 10 years earlier than the only surely deciphered date at Chichen Itzá; (3) 20 years earlier than the latest dated monument in the Old Empire region; and (4) 40 years later than the latest dated object from the Old Empire region.[8]

[8] This is a tubular jade bead found by Dr. Thomas Gann on the Rio Hondo in British Honduras in 1931. It records the date 10.4.0.0.12 *Ahau* 340 as Period-Ending.

The discovery of this late date on Stela 16 is perhaps the most important single contribution from this new site. It is another link in the ever-strengthening cultural chain binding the northern half of the Yucatan Peninsula to the southern half and indicates that the Old Empire came to its close, or at least to the close of monument building activities, some time during the first quarter of *Baktun* 10. Messrs. Ruppert and Bolles rejoined the rest of the expedition at Central Buenfil on the evening of April 24.

Early next morning a start was made by truck for La Gloria. A broken steering knuckle delayed the expedition 24 hours. Finally, at four o'clock on the afternoon of April 27, the expedition left La Gloria on two tram-cars for the fifty-mile ride to Kanasayab on the Champoton River, the head of navigation for motor-boats during the dry season, reaching there at four o'clock the next morning, where a motor-boat was waiting to carry the expedition and its outfit

AN ANCIENT QUARRY ON THE NORTHERN OUTSKIRTS OF THE CITY

TWO BLOCKS OF STONE ARE HERE SHOWN IN COURSE OF BEING QUARRIED FROM AN OUTCROP OF THE NATIVE LIMESTONE OF THE REGION.

LA GLORIA, CAMPECHE

ON THE ROUTE TRAVERSED BY THE CALAKMUL EXPEDITION. AT THIS POINT CHANGE WAS MADE FROM PLATFORM CARS DRAWN BY MULES TO A FIVE-TON MOTOR TRUCK WHICH CARRIED THE PARTY THROUGH THE HEART OF THE RAIN FOREST TO WITHIN A FEW MILES OF CALAKMUL.

to Champoton at the mouth of the river of the same name.

Here the expedition changed to a small schooner with auxiliary engine and proceeded by sea to Campeche. The Institution party, again most hospitably entertained by Mr. and Mrs. Brydon, left Campeche for Merida the next day. Messrs. Ruppert, Bolles and Stromsvik returned to Chichen Itzá, April 30, the writer and Mrs. Morley the next day, May 1, having been absent from Chichen Itzá just four weeks to the day.

Perhaps the greatest scientific contribution of the Calakmul expedition is the discovery of such a large and definitely Old Empire city having such a wealth of sculptured monuments so far north as the southern part of the state of Campeche. Previous expeditions, also working from the north, had found in central Campeche sites more characteristic of the New Empire cities of the north than of the Old Empire cities of the south. The discovery of Calakmul, with a definite Old Empire flavor, both in its architecture as well as in its sculptured monuments, at the very heart of the Yucatan Peninsula, midway between the earlier cities of northern Guatemala (the Old Maya Empire) and the later cities of northern Yucatan (the New Maya Empire), fills a geographic blind spot in our picture of Maya civilization and satisfactorily bridges the gap between the two regions.

A number of other archeological sites described as having sculptured monuments, located in the same general region as Calakmul, not only in southern Campeche but also across the line in the northern part of the Department of Peten, Guatemala, hitherto unvisited by scientific expeditions, were reported to the writer and it is planned to send another expedition into this new archeological sub-province during the next field season (1933). Indeed, perhaps the most important immediate result of the Calakmul expedition may be said to be the opening up, the first general notice, so to speak, of this scientifically significant region, the no-man's-land between the Old and New Maya Empires.

THE PARADOX IN NATURE AND MATHEMATICS

By Professor **AUBREY J. KEMPNER**

PROFESSOR OF MATHEMATICS, UNIVERSITY OF COLORADO

I. WHAT do we mean by a paradox? In the broadest sense, I should call paradoxical anything which conflicts with "common sense." In a narrower sense, I consider a paradox in science a statement which apparently admits of a valid logical proof, but which, on the other hand, contradicts facts or conclusions which are established beyond a doubt. It sounds in itself a little paradoxical to distinguish between "common sense" and a logical proof, but I think we may agree that there seems sometimes to exist only a small correlation between the two.

According to these definitions, a paradox is something relative. What at one stage of the development of a science or of the individual mind may be a paradox will, once we clearly establish a fallacy in the reasoning or once we accept as in agreement with common sense something which heretofore had not been acceptable, become simply a sophism or a puzzle. As Rousseau said, "A paradox is a truth which has come into the world a century too soon." Then, once we see what is behind it, it ceases to be a paradox. A true paradox is a real challenge to the human mind and a standing menace to the very laws of logical thinking.

II. I shall first illustrate by some simple examples what I have just said, and then pass on to some paradoxa which have either been degraded to sophisms or puzzles only within the last generation or two or which still retain their proud standing of true paradoxa.

We may pass over the age-old proof that 1 equals 2. We inflict it on algebra freshmen to illustrate the nonpermissibility of division by zero.

On a slightly higher plane is the following "proof" that any two given angles are equal. (Fig. 1a. b. c.) Let in each of the three figures $\angle CAB = \alpha$ and $\angle ABD = \beta$ be the two given angles, which are assumed distinct. In each figure AC is chosen of arbitrary length, and BD is made equal to AC. Erect the two perpendicular bisectors on AB and CD, respectively. It is at once seen that from $\alpha \neq \beta$ follows that these are not parallel, and they must therefore intersect, say at G. Then, in each figure:

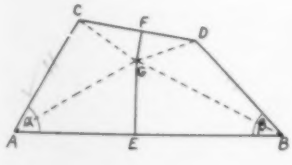


Fig. 1a

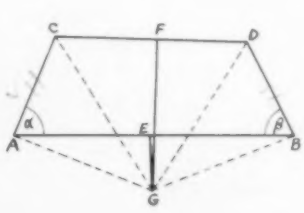


Fig. 1b

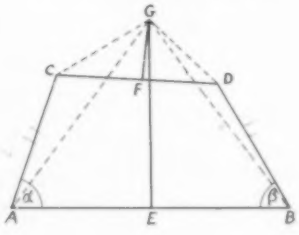


Fig. 1c

$\Delta AEG \cong \Delta BEG$; $AG = BG$;
$\Delta CFG \cong \Delta DFG$; $CG = DG$;
$\Delta ACG \cong \Delta BDG$.

Therefore $\angle BAG = \angle ABG$, $\angle CAG = \angle DBG$.

In 1a and 1c,
$\alpha = \angle BAG + \angle CAG$, $\beta = \angle ABG + \angle DBG$;
in 1b,
$\alpha = \angle CAG - \angle BAG$, $\beta = \angle DBG - \angle ABG$.

Thus, in every case, whether G lies inside the quadrilateral, or below AB, or above CD, we have $\alpha = \beta$, contrary to assumption. Apparently, all logical possibilities are accounted for; but a careful drawing will immediately reveal a neglected possibility.

Not quite so easy to see through is the following. (Fig. 2.) Consider a semi-circumference l_1 of a circle of diameter AB = d, so that $l_1 = \frac{\pi d}{2}$. As second step in our process, construct the two equal semicircular arcs l_2; as third step, the four equal arcs l_3; etc., etc. Clearly, the length of each wave line between A and B is equal to $\frac{\pi d}{2}$, that is, $l_1 = 2l_2 = 4l_3 = 8l_4 = \ldots = \frac{\pi d}{2}$. Now the argument is this: since at every step, however far we go, the length of the wave line is $\frac{\pi d}{2}$, it must also be $\frac{\pi d}{2}$ in the limit, when we repeat the process an infinite number of times. But then the wave line goes over into the diameter AB = d, and thus $\frac{\pi d}{2} = d$, $\pi = 2$.

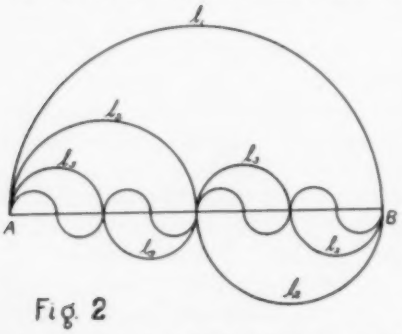


Fig. 2

True it is, of course, that, however small the diameters of the little circles be chosen, the length of the wave line is always $\frac{\pi d}{2}$. However, the argument holds only as long as we really are dealing with a wave line made up of semicircles. When we pass over to the limit, allowing the diameters of the small circles to reduce to zero, the resulting curve, the original diameter, is no longer of the same character as each of the wave lines l_1, $l_2 + l_2$, $l_3 + l_3 + l_3 + l_3$, etc. We shall have, it is true, $\lim_{n = \infty} \Sigma l_n = \frac{\pi d}{2}$ but this only gives us information concerning what happens when the diameters *approach* 0, and says nothing concerning the diameters being *equal to* 0. In this case, there is a clear error in logical reasoning.

By the same kind of argument, one "proves" $\sqrt{2} = 2$, using the constructions indicated by Fig. 3, and comparing the zigzag lines along the diagonal AB with the diagonal itself.

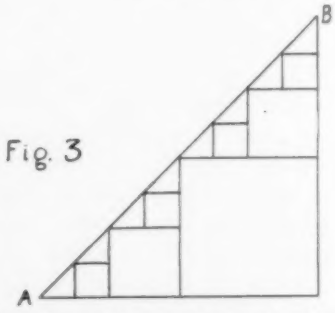


Fig. 3

An illustration of the same state of affairs, but more analytic in character, is the following: Consider the series $x(1-x) + x^2(1-x) + \ldots + x^n(1-x) + \ldots$. This is equal to $(1-x)(1 + x + x^2 + \ldots) \cdot x = (1-x) \cdot \frac{1}{1-x} \cdot x = x$, for $0 \leqq x < 1$. But for $x = 1$, one factor in each term of the original series is 0, and therefore each term is actually 0 (not: is approaching 0), and $0 + 0 + 0 + \ldots = 0$, even though we have an infinite number

of zeros. (To the mathematician, the world may have been created from an infinitesimal, but not from nothing, 0). So, for any x, $0 \leqq x < 1$, we have

$$\sum_{n=1}^{\infty} x^n (1-x) = x,$$

and also $\lim_{x \doteq 1} \sum_{n=1}^{\infty} x^n (1-x) = 1,$

but for $x = 1$,

$$\sum_{n=1}^{\infty} x^n (1-x) = 0$$

(not = 1). Graphically, the sum s(x) of the series, as a function of x, is represented by a 45°-line from (0, 0) to (1, 1), but from which the point (1, 1) has been broken out and dropped to (1, 0) on the x-axis, leaving the diagonal without any last point at its upper end. (Fig. 4.)

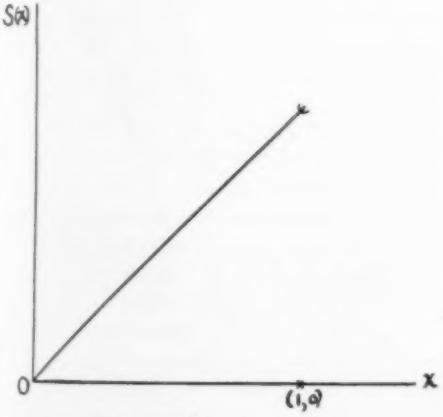


Fig. 4

Another mathematical phenomenon of paradoxical appearance is the so-called "conditional" convergence of a series, according to which the sum of an infinite series may sometimes be changed by merely changing the order in which the terms are written down. For example, $1-\frac{1}{2}+\frac{1}{3}-\frac{1}{4}+\frac{1}{5}-\frac{1}{6}+\cdots = \log_e 2$. But $(1+\frac{1}{3})-\frac{1}{2}+(\frac{1}{5}+\frac{1}{7})-\frac{1}{4}+(\frac{1}{9}+\frac{1}{11})-\frac{1}{6}+\ldots = 3/2 \log_e 2$. Now this is very remarkable, because the first and second series contain exactly the same terms, since, obviously (1) every term of the second series is in the first series (being taken from it), and (2) every term of the first series is bound to occur sooner or later in the second series. The trouble in this case lies in the assumption that in a series of an infinite number of terms we are at liberty to change the order of summation just as we may in a sum of a finite number of terms. In other words, we are without justification assuming that the commutative law of addition, $(a+b=b+a)$, which does hold for a finite number of summands, will necessarily hold also for an infinite number of summands. Here, again, certain logical possibilities were overlooked.

III. From the ancient Greeks we have inherited a fair number of paradoxa. I do not know whether their explanation was usually known to the philosophers proposing them, but there can be no question concerning their influence on the development of Greek thought. Some of them are, even to-day, of considerable philosophical and metaphysical interest, since they deal with the same notions of infinity, limits, continuity, etc., which are at the bottom of most of our modern paradoxa in mathematics.

I mention first the mathematical paradox of Achilles and the tortoise: Assume Achilles to run ten times as fast as the tortoise; yet Achilles can never overtake the tortoise if it is given a start (of, say, 100 yards; but the actual distance is quite immaterial in the argument). In ordinary English, the argument is that before Achilles reaches a point which was passed over by the tortoise, the tortoise had time to move ahead; when Achilles reaches the new point, the tortoise has again moved on, etc. It is granted that Achilles comes closer and closer to the tortoise, but it is claimed that he never will be ahead of it. Without the mathematical conception of an infinite geometrical progression with a

finite sum, it really is impossible to satisfactorily explain the logical difficulties.

Xeno's paradox of the arrow claims that a flying arrow must really be standing still, because, before it reaches any given point A, it has first to reach the point B midway between A and its point of departure, O; before it reaches this point B, it has first to reach the point C midway between O and B; and so on. Finally, the arrow can never get started at all. The difficulty lies in vaguely formulated notions of continuity.

A purely logical Greek paradox is the one of the lawyer and his pupil. A famous lawyer agreed to instruct a candidate in law on the following terms: If the candidate won his first case in court, he was to pay a stipulated sum to his teacher; if he lost his first case, the teacher had no claim against him. After completion of the course, the student refused to pay and was sued by the lawyer. The argument is: This is the pupil's first case. The lawyer says, "You must pay me whether you win or lose the case; if you lose, because you are sentenced to pay by the court; if you win, by the terms of our agreement!" "Nay," says the student, "in no case do I pay; if I win, I do not pay, by the verdict of the court; if I lose, I do not pay, by the terms of our agreement." It is of course not admissible to use two standards of decision, as is here done.

A similar paradox, of the crocodile and the child, will be familiar to many readers.

Of considerably greater philosophical interest than these is the famous paradox of Epimenides the Cretan: Epimenides of Crete said: "All Cretans are liars." Now, Epimenides is himself a Cretan, therefore what he says is a lie. Therefore the Cretans are not liars. But Epimenides is himself a Cretan; therefore what he says is true; therefore the Cretans *are* liars. *Now*, E. i. h. a. C. . . . , in infinitum.—Obviously, in order to draw the first conclusion, one must have E. say: "Everything that any Cretan says, is a lie." The second conclusion then is, "Not everything that every Cretan says, is a lie," and from this, and the fact that E. is himself a Cretan, does not follow that what he said is a lie.

As a last paradox in this class, I mention a modern one, the so-called Richard's antinomy, which has led to serious controversies. We admit definitions of numbers, but each definition is to contain not more than one hundred letters, digits, mathematical symbols and punctuation signs; words are to be in the English language. For example, 22 (two symbols), twenty-two (ten symbols), 2×11 (four symbols) all express the same number 22. Obviously, there exist only a limited number of possible combinations containing not more than one hundred of these symbols, and, therefore, a limited number of different numbers which can be described by their use. Therefore, there must be a largest number which can be described or defined by not more than one hundred symbols. So far, so good! But now consider the number defined as follows: *The largest number which can be described by one hundred or fewer symbols, plus one.* We have used seventy-two (less than one hundred) of our symbols (including the hyphens), and have established a bad contradiction, by constructing a number larger than the largest one which could be constructed. The source of error in this paradox lies at the bottom of some of our most vexing modern mathematical paradoxa. The totality we are dealing with, while it seems to mean something definite, is not really well defined.

IV. To most of us the belief is nearly inescapable that there exists a harmony between the phenomena of nature, in

"word" is a word;
"syllable" is not a syllable.

physics, chemistry and the other sciences, and the ability of the human mind to express the phenomena in what appeals to us as a natural manner, by the essential use of numbers, time and space. This belief is equally strongly ingrained in our minds, whether we believe in some marvelous dualism between the exterior world and the mechanism of our minds, or whether we consider the world, as it can be known to us, a creation of our minds, and the laws of nature nothing but an expression of the structure of our laws of thinking.

What do we encounter in reality? We very soon find in nature quite fundamental quantities, in terms of which many phenomena are described, and which one would expect to be of simple natural structure, whereas they are really of extreme complexity. Consider, for example, areas and circumferences of circles, and volumes and surfaces of spheres. These occur continually in the explanation of natural phenomena. But these mathematical concepts lead immediately to the number π, a number which has worried mathematicians for more than two milleniums. Let me say about π that it is one of the very worst kind of numbers one can have to deal with, a so-called transcendental number. However far one goes in the decimal expansion of $\pi = 3.1415926\ldots$, nobody has ever discovered even the slightest trace of any law for the digits; π has been computed to 707 places, but nobody in the world can at present from these 707 digits predict what the 708th digit will be. This is only one of its mildest forms of contrariness.

A similar situation, though mathematically of less complexity, confronted the ancient Greeks when they discovered that the diagonal of a square can not be represented as any fraction of the side, or, as we now say, that $\sqrt{2}$ is an "irrational" number. For centuries, this represented to the Greeks a true paradox; the question of "existence" of irrational numbers is very delicate, and the difficulties were not completely conquered before the latter part of the nineteenth century. The influence of this paradox on Greek thought and philosophy was very profound. It has been suggested that the very name *irrational* number bears traces of the difficulties encountered when such numbers were introduced.

Or, take yet another number, as important as π for the quantitative description of phenomena, and every bit as unnatural in its behavior, the famous number $e = 2.71828\ldots$. Whenever in a physical or chemical formula we run across a logarithm, its base is originally not 10, or any other reasonable number, but instead, this number e, for which the logarithm has first to be transformed to a base 10 before we can conveniently make computations.

Again, consider the measurement of angles, which surely represent a basic concept in the sciences. Our degree unit is avowedly entirely unnatural and artificial. All formulae in physics and mathematics are simpler when we use natural or radian measurement. But then what? The simplest of all angles, one we deal with incessantly, is the right angle, and this is now equal to $\pi/2 = 1.57079\ldots$ radians. It is enough to make one begin to sympathize with the legislature of one of our states which, many years ago, all but passed a law, according to which $\pi = 22/7$.

Finally, one of the quite fundamental concepts in nature is rotation about a point in space. Yet, to handle this in a satisfactory manner, it is desirable to introduce so-called Hamilton's quaternions; and these are again quite unnatural to common sense, since they do not obey the so-called commutative law of multiplication, that is, if a and b are

two quaternions we do not necessarily have $a \cdot b = b \cdot a$.

Does it not seem paradoxical in the sense that it offends our common-sense feeling concerning things in nature, as they are and as they ought to be?

V. We carry this idea a little further. Just as we feel that there should be a perfect correspondence between actual phenomena and the mathematical formulae expressing them in terms of quantities which appeal to us as natural and simple, so do we also have the strongest conviction that there must be a uniform, consistent method of expressing all phenomena, in the sense that the foundations of any one branch of science must not logically contradict the foundations of any other branch. (This conviction is of course at the source of the so-called conflicts between science and religion). In the past, this was considered a consequence of the very laws of thinking: that if the fundaments of one branch of science contradicted those of another, they could not both be "true." Consistency was axiomatic, anything else was unthinkable. To-day, there is a strong tendency to take a more empirical view. Our phenomenological way of dealing with nature seems to be leading us to the possibility of a schism. At present, for example, the radiation theory seems to be based on an *emission* theory, while the greater part of optics is based on an *undulation* theory. Now these two contradict each other. In former times, this would have been (and actually was) considered an intolerable state of affairs. At present, physicists apparently still hope that a reconciliation will some time be effected; but there also seems to exist a frame of mind which contemplates at least the possibility of further development along these separate lines, without ever integrating the two into a common system. Offhand, it looks a good deal like saying that on Monday, Wednesday and Friday the sum of the angles of a triangle shall be 180°, but on Tuesday, Thursday and Saturday it shall be 179°. The disturbing feature of the situation is that this probably could be done. But surely, in the name of common sense, which tells us that if one is "true," the other is "false," we have a paradox of the most serious nature. So serious, indeed, that for many orthodox thinkers the foundations of all true science appear undermined. The new, and terribly complicated, theories of Schrödinger, Heisenberg, de Broglie may possibly bridge the gap between these two conflicting assumptions, but perhaps only at the expense of other assumptions of an equally paradoxical nature

In pure logic and in the foundations of mathematics, we are encountering the same kind of perplexing trouble, in the question of the validity of the law of the excluded third, in the form in which it is commonly applied in mathematics.

To give one more illustration, compare the static model of the molecule which the chemist creates, with the dynamic model of the physicist. In this case we do perhaps not have a true paradox; it is thinkable that the chemist works with the static model instead of the dynamic, because it is sufficiently complicated for his purposes, and the dynamic model would not give him any clearer insight into his problems. However, it is also possible that changing from the static to the dynamic model would be inconsistent with the deductions and conclusions of the chemist from his static model.

We see that it is hard to cling to our old cherished notion of a kind of pre-ordained, pre-established harmony between nature, as reflected in its phenomena in physics, chemistry and the other natural sciences, on one hand, and our mind, expressing itself in terms of time, space and number, on the other hand.

VI. In a still broader sense, we encounter this paradox in an even more

fundamental aspect. There exists, and has existed since centuries, a large and influential school of scientific men to whom it is a dogma that all psychic actions and reactions are determined by the motions of atoms and molecules, and are uniquely decided by these motions. In other words, all psychic reactions obey, in a reflected manner, the law of cause and effect as we know it in physics. (However, it should be stated that this school is fighting with its back to the wall against certain theories which explain molecular motion in terms of probabilities of occurrences, in somewhat the same manner as a life-insurance company bases its business on purely statistical data.) When followed consistently, this mechanistic attitude leads to the doctrine of determinism, with a philosophy of fatalism hovering in the background. Here, at least, the human mind does not seem to be oppressed by the necessity of consistency, for, regardless of scientific convictions, nobody seems to act in life on the assumption that we do not possess freedom of action.

VII. Our next topic is again of considerable mathematical interest. When we draw a continuous curve, we shall ordinarily have at each of its points a definite tangent, that is, a definite direction. We may of course have on our curve a finite number of points for which there is no tangent, as at A, B, C in Fig. 5. But it is quite impossible for

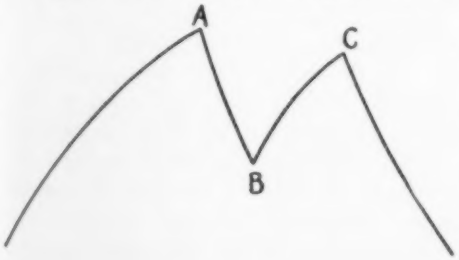


Fig. 5

us to conceive of a continuous curve which has at no point a tangent. The astounding thing is that such curves do exist; expressed in more technical terms, there exist functions, continuous in a given interval, and yet nowhere differentiable. A remarkably simple such function is indicated in Figs. 6a, b, c. The process here indicated is in each step to take the middle third of each segment, and over it to erect an equilateral triangle. This process is continued indefinitely, and the curve to be considered is to consist of the totality of all vertices so obtained. One sees rather easily that, if one remembers the definition of a tangent as the limiting position of a secant when the two points on the curve approach each other, the secant will have a tendency to swing around violently as the points come closer together, instead of coming to rest. I only mention that

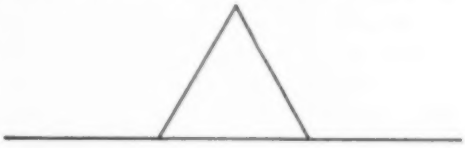


Fig. 6a

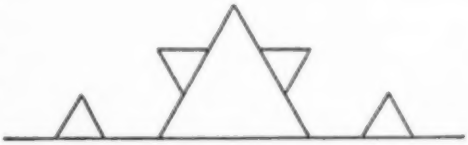


Fig 6b

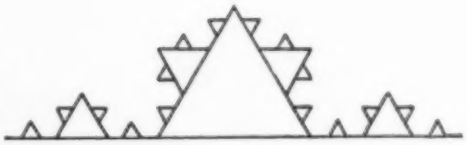


Fig. 6c

this curve has, as is very easily shown, the further remarkable property that the distance between any two of its points, measured along the curve, is infinite in length, however close the points seem to be.—The origin of the difficulty may be described as follows: from our knowledge of the curves which we are familiar with in ordinary mathematics, we deduce a property which we call "continuity of the curve." We then proceed to define this continuity in mathematical terms. Once this step has been taken, our hands are tied, and a curve is "continuous" when and only when it satisfies this technical definition. However, it may happen—as in this case—that our technical definition admits possibilities which we had not considered when the definition was set up.

Here we have a situation which looks like a true paradox until one goes very carefully and searchingly into the foundations of analysis. Such curves are often very expressively called crinkly curves.

It has even been suggested that possibly we deal in nature frequently with such crinkly curves. If we consider the barometric pressure as a function of the time, we get a zigzag curve like Fig. 7,

Fig. 7

and if we enlarge the curve, then, within the limits of accuracy of the recording instrument, we still have the same kind of zigzag curve. Have we really any guarantee that, however much we enlarge the scale, our curve will ever reduce to a decent smooth curve?

That phenomena in nature are at least continuous has been, up to recent times, axiomatically assumed. *"Natura non salta facit."* But it is rather new to assume that she may possibly operate in such freak curves. Incidentally, it may be mentioned, as entirely in keeping with our modern revolutionary tendencies in the interpretation of sciences, that we are beginning to doubt the continuous nature of phenomena in general. The so-called "Quantum" theories in their newer forms invade not only the physical fields of matter and energy, but also our metaphysical notions of space and time.

VIII. Our last examples have undoubtedly carried us into the domain of true paradoxa. The outstanding example at the present time, as far as natural phenomena in their connection with space and time are concerned, is the theory of relativity. To allow space and time to lose their individuality, to merge them into one more comprehensive unit, represented by "world-points," contradicts so utterly our naïve common-sense conception of space and time that we can accept it at all only by looking on it as the final step in a direction marked by many previous evolutions. Of these I should consider two of outstanding importance for our purposes:

The assumption of a spherical earth rotating about its axis introduced a very tame type of relativity of position in the sense that "above" and "below" acquired different meanings for different observers, according to their position; and a very tame type of relativity of time in the sense that two different observers would, for example, not simultaneously have noon, according to their position on different meridians. Most of us will remember the amazement and incredulity with which we, as children, received the information that the Australians were walking on the bottom of the sphere without falling off, and that Europeans were eating lunch when we were getting out of bed.

The other important step was the introduction of non-Euclidean geometry, in the first half of the nineteenth cen-

tury. As is now well known, this settled a problem of twenty centuries' standing, concerning the foundations of geometry. One of Euclid's axioms, namely, the statement that in a plane there is, through a point outside a given line, always one and just one line which does never intersect the given line, however far one goes on either side, occupies a different position in the system from that of any of the other axioms. We may formulate the distinction in this way: The other axioms may be verified in any given case by a figure; but this axiom, the so-called parallel-axiom, can not be so verified, because the lines would have to be continued indefinitely for verification, and this is not really possible. As the final outcome of centuries of efforts it was discovered that perfectly good geometries could be built up by leaving all other axioms quite unchanged, but replacing the parallel-axiom by either one of the two following axioms: (a) there is *no* line through the point which does not intersect the given line; (b) there is always *more than one* line through the point which intersects the given line. These two new types of geometry are the Riemann geometry and the Bolyai-Lobatschefski geometry.

The fact that assumptions (a) and (b) seemed contrary to common sense or conflicting with preconceived notions of the character of "space" delayed the development of the theory for centuries. The assumptions themselves appeared paradoxical.

By their admission, we run into another serious difficulty: we now have three different "possible" types of space, the ordinary Euclidean space, the Riemann space and the Bolyai-Lobatschefski space. In what sense may we assert that these three types of space all logically exist, since apparently each one logically contradicts the others? It becomes necessary to consider them as three illustrations of a general geometry comprehending them all, just as, in our concept of a triangle, we have acute, obtuse and right triangles, although the three types are mutually exclusive when applied to any particular triangle.

This problem has been of quite outstanding importance in philosophy and metaphysics apart from mathematics, because it deals with the question of the actual character of the space we live in. It is not easy to understand the implications of the question: Is our space Euclidean, or is it non-Euclidean? It is apparently a question which has to be determined by observation. In the depths of our mind there are no hidden resources which can assist us in forming a decision. Already the immortal Gauss made astronomical and terrestrial measurements for this purpose, but without definite results. Certain it is that if our space is not Euclidean, it is "very nearly" so. Here, also, we have a certain relativity in our concept of space; it is no longer absolute.

In this way the human mind has been gradually prepared for the theories of relativity, but the prediction may be ventured that it will be a long time before the theory will be generally accepted as at all satisfactory to our common-sense notions of space and time.

IX. As a last, extremely important and interesting example of paradoxa I mention some properties of rational numbers, which are from a purely logical standpoint completely understood, but which will always seem paradoxical when judged by intuition. This whole group is only about half a century old, and has brought in its train a flock of perplexing questions which are not yet completely and satisfactorily disposed of.

We recall the familiar representation of real numbers by points on a straight line, once the two points representing 0 and 1 are arbitrarily chosen. We shall consider only rational points, $\pm m/n$,

including positive and negative integers ($n = 1$). We may even for our purposes restrict ourselves to the interval $0 \leqq x \leqq 1$. Between any two distinct rational numbers of this interval, m_1/n_1 and m_2/n_2, there is at least one more rational number, for example, $(m_1 + m_2)/(n_1 + n_2)$, *and therefore an infinite number of rational numbers between any two rational numbers,* however close together these two were chosen. But this is only a beginning!

If we assume a finite universe, then, however large it may be, it can contain only a finite number of electrons; therefore, in any interval, however small—for illustration, consider the interval of length .0000001 between .2385724 and .2385725—we have infinitely more rational numbers than there are electrons in any finite universe.

But the rational numbers only begin to exhaust the totality of numbers in an interval. Besides the rational numbers we have so-called *algebraic* irrational numbers, and these are vastly more numerous (in a certain sense) than the rational numbers. And after these algebraic numbers come the so-called *transcendental* numbers, to which e and π belong, and these are (in every sense) infinitely more numerous than the algebraic numbers. Quite interesting, but not very deep-lying, apparent paradoxa can be formed along these lines. For example, we may show that of two segments, one longer than the other,

(a) the longer contains more points than the shorter;
(b) the longer contains just as many points as the shorter;
(c) the shorter contains more points than the larger.

It will suffice to "prove" (c). Let AB be the longer, A_1B_1 the shorter, segment. Assume them arranged as in Fig. 8. Then: (1) To every point in AB corresponds a point in A_1B_1; (2) There are points in A_1B_1 to which no point in

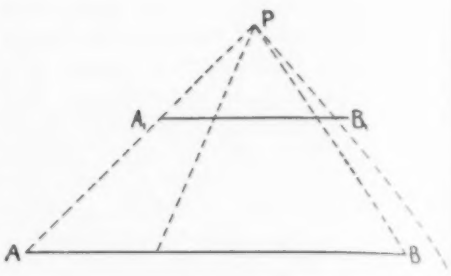


Fig. 8

AB corresponds.—The explanation of the "paradox" lies in the fact—which is hereby demonstrated—that it is not logically permissible to speak of the "number of points" in a segment in the sense that we speak of, say, the number of apples in a barrel, or the number (finite) of electrons in a finite universe.

More serious, because utterly irreconcilable with intuition, is the following paradox, the last one we shall mention.

We have seen that the rational numbers are so "dense" that in every interval, however small, we have an infinite number of them. How, then, is the following possible?

Consider all rational numbers in the interval $0 \ldots 1$, omitting, for simplicity, the points 0 and 1 themselves. Around each one of these, little segments can be placed, and the lengths of these segments can be so chosen that only an arbitrarily small fraction of the interval $0 \ldots 1$ is covered by any of the segments. To fix ideas, assume that each little segment is so placed over the corresponding number (that is, over the corresponding point) that the point is in the center of the segment; over the point 1/2 place a segment of length 1/100; over the point 1/3 place a segment of length $1/10^3$; over the point 2/3 place a segment of length $1/10^4$; over 1/4, $1/10^5$; over 3/4, $1/10^6$; etc. It is then true, although here not proved, that the sum of the lengths of all segments over all interior rational points

will be the sum of the geometrical progression $\frac{1}{10^2}+\frac{1}{10^3}+\ldots=\frac{1}{90}$. (It really is a consequence of the so-called "denumerability" of the rational numbers.) The fact that there is an enormous amount of overlapping of these segments acts in favor of the argument, as is easily seen.

X. I venture to hope that the foregoing treatment, brief and incomplete though it be, may help to bring out the following idea: In the development of science, we have always encountered the paradoxical. In the past, we have on the whole succeeded in gradually assimilating these paradoxa, sometimes quickly, sometimes after a struggle lasting over centuries. In some cases it has been necessary to revise fundamental concepts, such as our ideas of space. Up to quite recent times, we have succeeded in retaining intact our notions of logic, our ideas of cause and effect, and our conviction of an existing inherent harmony between the laws of the universe and the laws of the human mind. The work of the last generation has tended to shake our belief in the permanency and validity of these fundamental assumptions.

If our present-day paradoxa will also gradually permit assimilation within the old framework, science will have made tremendous steps in advance, but in the direction of the development of the past two thousand years. If the new paradoxa refuse to fit into our old framework, the human mind faces a situation more serious than anything it has ever before been exposed to—a situation which must mean either a retrogressive shallowness in our fundamental conceptions, or an intensification in understanding far beyond anything at present considered possible.

GASOLINE AND LUBRICATING OIL

By Dr. GUSTAV EGLOFF

UNIVERSAL OIL PRODUCTS COMPANY, CHICAGO, ILL.

FORTY years ago there were just four automobiles in the United States. That was before the gasoline age, and kerosene was king of the oil industry. Gasoline was a waste product from the refining of crude oil during this period.

From 1859 to about 1905, gasoline, always present in crude oil, was a nuisance to the refiner. He was at his wit's end to get rid of it. He ran it into streams, rivers and lakes until the law called a halt due to the many resulting fires. The unscrupulous dealer adulterated his kerosene with the worthless stuff, resulting in many disastrous lamp explosions. In 1871, in New York City, the great chemist, Professor Charles F. Chandler, discovered that there were kerosenes being sold which were pure gasolines. Again the law intervened and drastic measures were taken to remedy this evil.

The advent of the motor car changed the picture. Motor cars burned gasoline, so gasoline became the chief product desired from crude oil. The number of automobiles and trucks increased more rapidly than the facilities for making gasoline. There are now 26,000,000 autos in the United States.

At the same time demand for kerosene was falling off. Oil lamps were being rapidly supplanted for lighting by manufactured gas and later by electricity. The oil refiner's position was completely reversed. His problem now was to increase his output of gasoline and decrease his output of kerosene. As some unscrupulous dealers earlier had mixed as much of their worthless gasoline with kerosene as possible, they now tried to get rid of their unwanted kerosene by mixing it with gasoline.

For a time it looked as though the oil industry would never be able to keep up with the mounting demand for gasoline. Prophets of gloom predicted a shortage of crude oil, fearing that the oil resources would last only a few years.

Such prophets failed to take into consideration the manifold applications of science to the oil industry. There never was a real shortage of oil and there is evidence present that there will be enough for at least a century. While the application of scientific methods has brought about the discovery of vast new pools of oil, science has made perhaps an even more important contribution to the oil industry and to the motorist in the field of gasoline production. The oil industry is producing at the yearly rate of 18,000,000,000 gallons.

Not only has the chemist shown the way to produce more than 300 per cent. increased yield of gasoline from crude oil in 20 years, but in addition he has produced a new and superior gasoline to that distilled from crude oil in the ordinary way. This was accomplished through the development of the cracking process.

Cracking produces gasoline of different chemical composition from that naturally present in crude oil. Instead of merely boiling off the gasoline fraction of petroleum, cracking subjects the oil to intense heat and pressure; temperatures of the order of 950° Fahrenheit and pressure of 400 pounds. The heat strives to force the oil molecules away from each other while pressure at the same time is forcing them closer together. In this Titanic struggle of forces the large hydrocarbon molecules from oils such as kerosene, gas oil, fuel

oil, or even crude oil, which will not operate a motor car, are shattered into small gasoline molecules which burn evenly in the engine and do their work quietly and without fuss.

A large part of the chemical research continuously going on in the oil industry is directed toward improving the anti-knock qualities of its gasoline. Anti-knock value to-day is expressed in "octane number." High octane gasolines mean smoother, quieter operating motors, with greater power output or more miles per gallon. They are a result of the modern cracking process. The gasoline present in crude oil, which nature has been forming through millions of years in the depths of the earth, is no longer suitable for the modern, high compression motor; hence it is being cracked into gasoline having the type hydrocarbons which will burn slowly in the engine. Nature's gasoline burns too rapidly and knocks violently during combustion in engines of most modern cars, which means harsh running and loss of mileage.

So we crack nature's oil—even gasoline—to make anti-knock motor fuel.

Motor-car manufacturers have been quick to take advantage of the constantly improved quality of gasoline to better the operation of their cars by increasing compression pressure. The higher the compression under which combustion takes place in the engine, without knocking, the greater the miles per gallon of gasoline. It is significant that nine years ago only four per cent. of all the cars manufactured had a pressure in the cylinders of 105 pounds or over, while in 1933 over ninety-three per cent. of the cars operate at this pressure. This increase or greater power output of motor-cars, could not have been accomplished without the development of the cracking process, which produces high anti-knock gasoline.

Hand in hand with progress in making anti-knock gasoline has gone development of means for preserving this value in gasoline and preventing the formation of troublesome gum. These ends have been accomplished by the discovery and perfection of inhibitors.

Inhibitors may be looked upon as chemical policemen which prevent air from reacting with the sensitive unsaturated hydrocarbons in gasoline. Thus they prevent any gum formation upon storage, or when the fuel is burning in a motor.

The development of inhibitors to prevent oxidation of gasoline made it possible to save millions of dollars a year which would be spent for chemicals to refine the gasoline to a marketable product. By the use of inhibitors, added in the merest traces, purification may be eliminated or modified, reducing loss of gasoline, preventing gum formation, and preserving anti-knock properties, as well as producing a better all-around motor fuel for the modern automotive engine.

The volatility of gasoline is another important property. "Volatility" in this sense is the ability of the gasoline to vaporize readily.

A gasoline which vaporizes readily is desirable for winter driving because it makes for quick starting. In summer, however, if the gasoline is too volatile it will even vaporize before it enters the manifold, causing gas bubbles which shut off the gasoline and stop the engine. This is known as vapor lock and frequently puzzles motorists who are not familiar with motor operation.

As a consequence oil companies regulate the volatility of their gasoline to a nicety so that it will perform properly whether the atmospheric temperature is thirty below or over a hundred. With better motor fuels and better cars, the motorist to-day gets twice as much value for his gasoline dollar as he ever got before.

Speed boats have traveled over 120

miles per hour, automobiles over 250, and airplanes over 400. Common cruising speeds for modern motor-cars are now about 65 miles per hour while ten years ago it averaged 35.

The motors which propel these vehicles must not alone be gasolined, but require careful lubrication. These mighty speeds throw a heavy burden upon the oil industry to provide lubricants which will keep the moving mechanisms apart.

The motor cylinders are fiery furnaces with temperatures of over 3,000 degrees Fahrenheit produced by the burning gasoline. Pistons in the cylinders move at 10,000 revolutions per minute. Under these conditions the lubricating oil must not materially change its viscosity or develop carbon to foul the cylinders. Moreover, it must have sufficient fluidity to permit the motor to start readily at arctic or desert temperatures.

More progress has been made in the manufacture of lubricating oils in the last few years than in the preceding thirty. Few people realize the vast difference in lubrication requirements between an engine driven at 65 miles an hour and one at 35. Up to 35 miles an hour, lubrication affords few problems. But at 65 the difficulties are greatly increased, and the punishment of lubricating oils is enormous when a motor drives a plane through the air at a speed of over 400 miles.

Another trend in motor-car design is toward lower body styles to facilitate higher speed and greater acceleration on the road. In order to maintain the necessary road and body clearances, smaller rear axles are required. Due to this trend toward smaller gears, higher engine torque, tooth pressures and rubbing velocities, a point is being approached where rear axles can not be lubricated with ordinary oils in a satisfactory manner.

Hypoid and worm gears, which are being adopted for the reason mentioned, operate under conditions of higher rubbing velocity than spiral bevel gears, and the use of these gears makes it necessary to provide special lubricants which will resist extreme-pressure operation. New extreme-pressure lubricants made up of blends of petroleum oils, saponifiable oils, and sulfur have been developed for such use.

To meet the modern lubrication demand careful selection of crude oils is essential. Crudes vary widely in quality, even when derived from different wells in the same oil field. Consequently, crude oils from particular wells in an oil field are specifically segregated for their lubricating oil quality alone.

Improvements in the process of refining have been made. The oils are distilled under vacuum and closely fractionated. Refrigeration temperatures of sixty below zero are being used to separate the wax from the oil. In some cases inhibitors are used to prevent the formation of crystalline wax in the lubricant. Solvent extraction, too, selectively removes from the oil those fractions having the best lubricating quality.

Synthetic lubricating oils have also been developed by hydrogenation and by the polymerization by aluminum chloride of oil produced by cracking. Not only have lubricating oils been developed to meet present motor-car requirements, but an immense amount of research is going on to anticipate the lubrication needs of the future. Millions of dollars are being spent by the oil industry in research to improve the quality of gasoline and lubricating oils, so as to anticipate the speeds of the future.

THE RELATIVE NUTRITIVE VALUE OF LAND AND WATER PRODUCTS

By Dr. D. BREESE JONES

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ALL living things, in the last analysis, are dependent for their food supply upon the elemental constituents of the soil and of the air. Plants take the elements required for their nutrition, such as potassium, calcium, phosphorus, carbon, hydrogen and nitrogen, and manufacture them into sugars, starches, proteins, oils, mineral salts and vitamins. Animals can not manufacture these food compounds for their requirements, but are dependent for them upon the synthetic processes of plant life.

There is, therefore, a continual withdrawal from the soil of those elements which are essential for plant and animal nutrition. Under primitive conditions of life this material was returned to the soil with quite uniform distribution, so that the original fertility of the soil was largely maintained. Civilization in this respect has disturbed the balance of nature. The produce of the land is harvested, transported and, to a large extent, concentrated in certain areas, principally the large cities.

The soil is and always has been impoverished through another influence, namely, the leaching effect of rains, which carry away tremendous quantities of the elements of soil fertility. What becomes of all the material removed from the land by the two combined influences referred to? It finds its way ultimately into the sea, carried by streams and rivers, and through the agency of the sewage disposal plants of our cities. These elements of plant and animal nutrition, transferred from the soil to the sea, can be utilized by man and partly restored to the land only by farming the sea. This consideration lends special interest to a discussion of the relative biological value of land-farmed and marine-farmed products.

In animal nutrition food performs three functions, (1) it yields energy, (2) supplies material for the construction of body tissues, and (3) regulates many physiological processes. In order that a diet may satisfactorily perform these functions it must contain adequate amounts of protein, fat, carbohydrate, inorganic materials, and vitamins. Of course, water is essential and also a certain amount of indigestible material for roughage.

PROTEIN

The chief function of protein in nutrition is to supply material for the construction of nitrogenous tissues, such as muscle, skin and hair. Protein also enters, to a greater or less extent, into the composition of practically every tissue in the body. Although fats and carbohydrates are the fuel material in food which supplies most of the heat and energy required by the body, proteins also contribute to the energy requirements of animals.

During the process of alimentary digestion proteins are converted into some twenty or more relatively simple compounds, which are called amino acids. These compounds may be regarded as the units or building stones of which proteins are composed. It is the amino acids and not the proteins which are assimilated. The proportions in which the amino acids occur in different proteins vary enormously. Some proteins are deficient or entirely lacking in one or more of them. It is because of

these differences that proteins vary so much both in their chemical and physical properties and also in their nutritive value. Gliadin, one of the chief proteins of wheat, is deficient in the amino acid lysine; zein of corn is almost entirely lacking in both lysine and tryptophane; gelatin is lacking in five of the amino acids. Wheat and corn, however, contain proteins other than gliadin and zein, which are better sources of amino acids. Consequently, in the whole grains these better proteins compensate in part for the deficiencies of gliadin and zein. Four of the different amino acids found in proteins have been proved to be essential for the normal growth and development of animals. They are lysine, cystine, histidine, and tryptophane. When the protein in the diet is lacking in any one of these four amino acids nutritional failure and death will eventually follow, no matter how much other food may be eaten.

In discussing the relative biological properties of the proteins of land and marine grown products, I shall first point out some general characteristics of the proteins of land products as a class.

The following materials constitute the most important land sources of food proteins: Meats and animal products, milk, cheese, eggs, cereals and seeds, nuts, vegetables and forage crops. Very striking differences in the nutritive value of proteins are found in some of these food materials. Analyses of the isolated and purified proteins of meat, milk, eggs and nuts have shown that these proteins are nutritionally complete, that is, they contain all the known essential amino acids in sufficient quantities to meet the normal nutritional requirements of animals.

The proteins of seeds, on the other hand, show striking differences in their nutritive quality. The chief proteins of most of the cereal grains are deficient or lacking in one or more essential amino acid. Wheat gliadin and rye gliadin are deficient in lysine, tryptophane, and histidine; zein, the chief protein of corn, contains no tryptophane nor lysine, and is deficient in histidine; hordein, the protein of barley, is low in all three of these amino acids, and oat gliadin is lacking in lysine and tryptophane.

In contrast to the seeds of cereal grains, those of the oil seeds and nuts which have been studied, including linseed, hempseed, peanuts, soy-beans, cottonseed, almonds, brazil nuts, and others, possess proteins of high biological value. They contain high percentages of the amino acids which are deficient or lacking in the cereal proteins.

Studies which we carried on a few years ago on the proteins of several kinds of beans disclosed an amino acid deficiency which is characteristic of the proteins of a certain class of legume seeds, including the common white navy bean, lima bean, adsuki bean, mung bean, velvet bean, cow-pea, and the lentil. The total proteins of these seeds are so deficient in cystine that young experimental laboratory animals will decline in weight and survive for only a short time when these seeds constitute the sole source of protein in their diet. That a deficiency of the amino acid cystine in these proteins was the cause of the nutritional failure was demonstrated by the fact that when a small quantity of cystine, amounting to only two or three tenths of one per cent. was added to the same ration, growth at a normal rate followed.

Compared with the proteins of other foods, those of vegetables and forage material have been only little studied. Such information as is available indicates that these proteins have a high biological value.

Fish, oysters, clams, crabs, lobsters, shrimp and scallops include most of the marine nitrogenous food products. The proteins of these foods have not been studied nearly so much as the proteins

of the land-farmed products. The amino acid content of the muscle tissue of several varieties of fish, of scallops, and shrimp has been determined. The biological value of the proteins of some of these products has also been determined by feeding tests with experimental animals. The proteins of all the marine foods which have been studied contain in satisfactory amounts all the nutritionally-essential amino acids. Osborne and Jones found that although there were differences in the percentages of some of the amino acids in the muscle tissue of different classes of animals, including fish, scallops, chicken and ox, the results "did not show such wide differences as are found between some of the different kinds of protein of vegetable origin." More recently, analyses of the muscle tissue of a representative crustacean, the shrimp, made in the Bureau of Chemistry, gave percentages of amino acids closely agreeing with those found for the other types referred to. Because of the difficulty of obtaining preparations of the proteins of oysters and clams suitable for amino acid determinations, no data are available showing their amino acid composition. However, the fact that young experimental animals grew to maturity at a satisfactory rate and were well nourished on a ration containing no protein other than that furnished by whole dried oysters and clams showed that the proteins of these mollusks are of satisfactory biological value. In general, it can be stated that marine animal life furnishes proteins quite similar, with respect to their biological value, to those of land-farmed animals and superior to the proteins of certain seeds, such as the cereal grains and beans of the genus *Phaseolus*. The extensive use of fish meal in stock and poultry feeds finds here additional justification, in that the amino acid composition of fish proteins is well suited to supplement the proteins of various grains.

Carbohydrates and Fats

Many land-farmed food products are very rich in carbohydrates. From one half to three fourths of the weight of the dried matter of many cereals, seeds, tubers, roots, and fruits consists of starch or sugars. Fats are also present in large proportions in many animal and plant products of the land, such as nuts, cheese, soy-beans, olives, avocados, linseed, cottonseed, and peanuts.

Many nuts contain from 65 to 70 per cent. of oil.

Fish and shell-fish excel as sources of dietary factors necessary for the formation of body tissues and for the regulation of certain physiological processes rather than in their value as a source of fuel or energy.

Fish contain less fat, as a rule, than the higher animals. Shell-fish are not rich sources of fats and carbohydrates, although they are not lacking in these dietary factors. The edible portion of mollusks and crustaceans contains from 1 to 2 per cent. fat. Unlike most types of animal food they contain some carbohydrate, in the form of glycogen, or animal starch. This carbohydrate is said to be wholly digestible. It amounts to about 3 to 4 per cent. of the oyster, and about 5 per cent. of abalone.

Mineral Elements

The excessive popular attention given to vitamins has somewhat obscured the general appreciation of the significance of the inorganic or mineral constituents of foods. The inorganic salts comprise a little over one fifth of the moist tissue weight of the body and are found, for the greater part, in the bones and skeletal structure. They are also present in all the tissues and fluids of the body and serve vital functions in many of the life processes. They maintain the delicate balance between the acid and alkaline reaction of the blood and other fluids; they take a part in the coagulation of the blood, in reproduction, in digestion,

and even govern to a degree the state of excitability and repose of an animal.

The most commonly known elements which regularly occur as constituents of animal tissues include calcium, phosphorus, potassium, sodium, iron, chlorine, sulfur, magnesium and iodine. In addition to these, traces of copper, zinc, boron, manganese, silicon and fluorine are usually found, some of which have been shown to be essential for the nutrition of plants and animals.

Minerals

Iron has been long known to be an important constituent of blood corpuscles and is involved in the transportation of oxygen from the lungs to the cells of the various tissues in the body. About 15 milligrams of iron are required daily by an adult person. The nine land foods containing iron in the largest amounts are listed in the following decreasing order: Lima beans, peas, whole wheat, lean beef, spinach, oatmeal, raisins, eggs, and green vegetables.

Work done at the University of Wisconsin has demonstrated the importance of *copper* in the diet. Before the iron in the food can be assimilated there must be present minute traces of copper. A disease called nutritional anemia, characterized by a low supply of red corpuscles in the blood, can be produced in animals by feeding them a ration lacking in iron. Addition of suitable quantities of iron to such a ration produces no improvement in the condition of the animals, but when small quantities of copper are added along with the iron, rapid recovery follows. Of the land-farmed products the following 10 are reported to contain the most copper:

Copper Content of Some Land Food Products

(Quantity of copper expressed as milligrams per kilo of the fresh food)

Wheat germ	48.0
Oats	17.1
Almonds	13.0
Kidney beans	10.0
Rye	7.5
Peas	7.2
Asparagus	7.0
Maize	6.8
Lentils	6.6
Barley	6.5

The American dietary is probably more deficient in *calcium* than in any other one inorganic ingredient. Calcium is essential for bone and teeth formation, and it enters into the composition of many other tissues of the body. It plays a part in the process of blood coagulation. Children need more calcium than adults, requiring about 0.75 to 1 gram daily, an amount contained in one quart of milk. Land-grown foods rich in calcium are milk, cheese, carrots, cabbage, turnips, prunes, beets and oranges.

Phosphorus is also needed for bone structure and for the nuclear structure of the cells. Adults require about 1 to 1.5 grams daily. Good sources of phosphorus are milk, egg yolk, cheese, whole wheat, beans, oatmeal, lean beef, nuts, fruits and vegetables. A lack of either calcium or phosphorus may be followed by rickets, a disease common among children.

Magnesium, sodium, potassium, chlorine and *sulfur* are so widely distributed in foods that the question of their deficiency in the diet is generally of little concern. McCollum has recently demonstrated that a lack of magnesium in the diet of rats produces a dilation of the capillaries, tetany, and other symptoms of abnormal condition. He also found that manganese, a common constituent of foods, is essential for normal reproduction in animals.

Iodine, an essential constituent of the thyroid gland, is present in the body in a mere trace. It plays, however, a very important rôle in human health and life. Iodine in particular is one of the mineral elements in which the soil in certain areas is deficient. The relation between

deficiency of iodine in the diet and the incidence of goiter is well known. Certain cities in goitrous regions have introduced iodine into the drinking water supply.

As a class, most of the cereal grains, tubers, tropical seeds and nuts are deficient in calcium and sodium, and in some cases in iron and iodine. Increased incidence of disease in cows has been observed when they were fed rations deficient in calcium. It has been found that the growth, health and reproductive capacity of pigs fed rations consisting of cereal grains were improved when salt mixtures were added to the rations. A high mortality of sheep in a certain section of Michigan disappeared when mineral salts found in deposits near one of the Great Lakes were added to their diet. Animals grazed continuously on certain areas in New Zealand have been shown to suffer from malnutrition due to a deficiency of iron. The trouble was avoided by transferring the animals to pastures richer in iron. The symptoms were also relieved by giving them iron salts. In a certain section of Montana where the supply of iodine is low, an enormous loss of young pigs was shown to be caused by a deficiency of iodine in the food of the cows. Administration of small doses of potassium iodide prevented the high mortality.

Land crops depend chiefly for their inorganic constituents upon the soil. Unequal distribution of minerals in the soil is reflected in corresponding variations in the quantities of these elements found in the crops grown on those soils. In turn the animals are dependent upon the plant products and, to a lesser degree, on the water supply for the inorganic elements needed for their nutritional requirements.

Large bodies of water, particularly the sea, contain a much more uniform and constant supply of inorganic food. The ocean is a vast storehouse wherein has accumulated throughout countless ages a mixture of practically all the elements found in the earth's crust, as they have been leached from the soil and carried down by the rivers and streams. Marine-farmed products are, accordingly, an excellent source of inorganic elements. Seaweeds have been long used as a source of potassium and iodine. Schemes have been proposed for recovering gold from sea water.

Sea-food, particularly shell-fish, is known to contain, besides the mineral constituents which have been long recognized as biologically essential, such as calcium, phosphorus, iron, and sulfur, also those elements which more recently have been demonstrated to be integral constituents of living tissues.

Several investigators have shown that oysters contain copper in quantities ranging from 4 to 3,300 parts per million.

Remington and collaborators found that oysters contain copper in greater concentration than is found in any other plant or animal. By feeding experiments with rats they showed that oysters possess marked curative properties in nutritional anemia.

It is recorded that the ancients used seaweed for the relief or cure of goiter. Just in what way seaweed was beneficial was, of course, unknown, not only to them, but to hundreds of generations that followed them. To-day, we know that one type of goiter is a consequence of insufficient iodine in the diet, and that seaweed is one of the richest sources of this element. Tressler and Wells state, "Oysters, clams and lobsters contain more iodine than any other marine food" and that "they contain about 200 times as much iodine as milk, eggs or beefsteak, shrimp 100 times as much and crabs and most ocean fishes 50 times as much."

The presence of manganese in oysters has also been established.

Other mineral elements have been found in shell-fish, which can not yet be

included in the list of elements demonstrated to be beyond question nutritionally essential. It has been known for years that marine plants and animals contain heavy traces of arsenic. Chapman found arsenic in the following products, the quantities being expressed as As_2O_3 in parts per million of the wet substance: Oysters, 3 to 70; shrimp, 12 to 40; lobsters, 18 to 110; crabs, 36 to 70; flatfish, 3 to 10. Fresh-water fish, including pike, perch, roach, snails and crayfish, were all found to contain arsenic.

Oysters were also found to contain zinc in quantities ranging from 70 to 2,100 parts per million and lead in quantities varying from 10 to 400 parts per million of the dry edible substance.

Whatever mineral elements may be added in the future to the list of those already accepted as essential for the normal nutrition of animals, we are justified in expecting them to be present in the crops of the sea.

Vitamins

Vitamins are doubtless the most popularly known of the different food factors. We read about them in books, magazines, newspapers, advertisements and labels on packages; we hear about them on the street, over the radio, and from the platform. Vitamins have been recognized as definite food components for only about 20 years. Animals can not grow, be healthy or live long without vitamins. Mere traces of them only are required. At present six different vitamins are generally recognized. They are known as vitamins A, B, C, D, E and G.

Without *vitamin A* young animals can not grow. Their vitality becomes lowered and they are less able to resist infections and disease, particularly those of the respiratory tract. A characteristic disease of the eyes usually appears. Administration of vitamin A promptly cures this affliction. *Vitamin B* is called the antineuritic vitamin. Absence of it in the diet results in loss of appetite, arrest of growth, derangement of the nervous functions, and other disorders. A lack of *vitamin C* in the diet causes scurvy, and, for this reason, it is known as the antiscorbutic vitamin. Deficiencies in bone and tooth development are closely connected with vitamin C deficiency. Formerly scurvy was common among sailors, soldiers and others compelled to live on dried and preserved products without fresh fruits or vegetables.

Vitamin D is called the antirachitic vitamin. Rickets, a disease widely prevalent among children, is caused chiefly by improperly balanced proportions of calcium and phosphorus in the diet. The utilization of these elements is controlled largely by vitamin D. Sunlight or ultra-violet light is also effective in curing and preventing rickets, and is in effect a substitute for vitamin D. *Vitamin G* is usually associated with vitamin B. Deficiency of this vitamin in the diet results in retardation of growth, digestive and nervous disturbances, lowering of vitality, and ultimately in the appearance of skin lesions characteristic of the human disease, pellagra. Although the symptoms produced in animals by feeding them a diet lacking in this vitamin resemble those of human pellagra, it has not been definitely proved that they are identical. *Vitamin E*, known as the antisterility vitamin, is required for the normal reproduction of rats. There are no data, however, to show that it plays a rôle in human reproduction.

As a class, fresh vegetables, particularly the green leafy vegetables, are the best general source of vitamins. With few exceptions, they are an excellent source of vitamins A and C. Nearly all those tested contain vitamin B in goodly quantities. Some are known to contain vitamin E, green lettuce being an excellent source. Vitamin G is also present in beet greens, spinach, kale, onions, water cress and other vegetables. Veg-

etables, however, are a very poor source of vitamin D.

Cereals constitute probably the one most extensively used food item of the vegetable kingdom. They are, however, very limited as a general source of vitamins. As a class, whole cereals, seeds and nuts supply liberal quantities of vitamin B, this vitamin being located chiefly in the seed germ, or embryo. Wheat germ and rice polishings are among its best sources. Wheat germ is also one of the richest known sources of vitamin E. On the other hand, this class of foods is a poor source of vitamins A, C, and D. One noteworthy exception is yellow corn, which is a good source of vitamin A.

Eggs and *dairy products* occupy an important position as a source of vitamins. Egg yolk is an excellent source of vitamins A and D. It also contains vitamins G and E in liberal quantities, and is a fair source of vitamin B. The white of eggs, however, is a poor source of all the vitamins, excepting vitamin G. Butter is rich in vitamins A and D. It contains some E, but little or no B or C. Fresh, raw milk contains in addition a fair supply of vitamins B, G, and C.

Fruits rank as one of the best sources of vitamin C, notably oranges, lemons, grapefruit and strawberries. Bananas, pineapples, and prunes are fairly rich in A. Most fruits are also good sources of B, but are low in vitamin D content.

Muscle meats contain but little vitamins A, B, C, and D, but they are a fair source of G. The *internal organs* of animals, however, particularly the liver, heart and kidney, are good sources of vitamins A, B, G, and C, but they are low in vitamin D content.

Vegetable oils, such as olive oil, cottonseed oil, coconut oil, and peanut oil, may contain some vitamin A and vitamin E, but they are practically devoid of the other vitamins.

From this brief survey it is to be noted that vitamins A, B, and C are widely distributed in the land-farmed food products, but that most of them are deficient in vitamin D. Herein lies a differentiation between them and marine-farmed products.

Cod-liver oil is the best known and most widely used natural product as a source of vitamin D. In 1929 nearly 263,000 gallons of crude cod-liver oil were produced in the United States. This represents only about one tenth of the cod-liver oil used for animal feeding, 90 per cent. being imported. Cod-liver oil is also one of the richest sources of vitamin A. It has been shown by several investigators that the liver oils of fish other than the cod, namely, the shark, skate, ling, plaice, coal-fish and haddock, are rich in vitamin A.

Fish oils are obtained from fish and from fish offal, a by-product of the fishery industry. The material is heated and the oil expressed. The cake is used as fish meal for feeding. The total product in 1929 of fish oils, other than liver oils, was in excess of 12,000,000 gallons.

Interesting studies have recently been made in a series of studies on fish oils by Nelson, Manning and Tolle. This work was carried on cooperatively by the U. S. Bureau of Fisheries and the U. S. Bureau of Chemistry and Soils. Tests were made to determine the relative value of the oils obtained from tuna, sardine, menhaden, salmon, Alaska herring, and Maine herring, as sources of vitamin D. If an arbitrary value of 100 be assigned to cod-liver oil as an expression of its vitamin D potency, then the oils tested would have the following relative vitamin D values:

Tuna	125
Sardine	100
Menhaden	75
Salmon	50
Alaska herring	30
Maine "	15

Tests made later on menhaden oils, especially prepared under different conditions so as to avoid as far as possible any destruction of vitamin A, showed

that such oils were fully equal in vitamin D potency to medicinal cod-liver oil.

Burbot oil, prepared under commercial conditions, was shown to be from 3 to 4 times as rich in D, and from 4 to 10 times as rich in vitamin A as good grades of medicinal cod-liver oil.

The fish oils are used chiefly in making soap and as drying oils, and to some extent for sizing leather and tempering steel. Much fish waste is also discarded without attempting to recover the oil. These oils, cheap and excellent sources of vitamin D, are finding increasing use in stock and poultry feeding.

A little more than a year ago, tests for vitamin A and vitamin D potency were made on different samples of salmon oil. Three different preparations of oil were used, a commercial salmon oil, an oil from commercially canned salmon, and an oil prepared in the laboratory from salmon offal, a waste from the salmon canning industry. Oils from the offal of different species of salmon showed wide variation in their vitamin A potency. Oils showing a distinct reddish color, obtained from chinook and sockeye salmon, contained much more vitamin A than oil from chum, which was practically free from color. Some of the oils contained as much vitamin A as good grades of cod-liver oil and twice as much vitamin D.

Clinical studies on thirteen children with active rickets, recently conducted to test the value of salmon oil in the treatment of this disease, showed that salmon oil was more effective than the average medicinal cod-liver oil and compared favorably in its rapidity of action with viosterol.

Tolle and Nelson state, "Statistics show there are approximately 300,000,000 pounds of canned salmon produced annually in this country. This fish contains from 6 to 10 per cent. of oil. From the data obtained on the vitamin D content of the oil in canned salmon, it is quite apparent that there is more vitamin D in the canned salmon sold in this country than in the cod-liver oil used for both human and animal feeding."

Because of the meager information on the vitamin content of shell-fish, the Bureau of Chemistry and Soils undertook a study of the vitamins in oysters, clams and shrimp. Oysters constitute the most valuable fishery product of the United States. The annual yield in this country is about 30,000,000 bushels. Clams come next in the order of importance. Randoin, in France, had previously showed that oysters were effective in preventing scurvy in guinea-pigs. Working with fresh Chesapeake oysters, we found them to be a good source of vitamins A, B, and D, but rather deficient in vitamin E. First generation females reared only 14 per cent. of their young. Six second generation females produced only 2 litters, comprising 6 young, none of which were reared.

Two species of clams, commonly known as "hard-shell" clams or "quahaugs" and "soft-shell" or "sand" clams, were used in our studies. Although both oysters and clams were found to be good sources of vitamins A and D, one striking difference between them was observed. Unlike oysters, which compare favorably as a source of vitamin B with foods which are recognized as excellent sources of this vitamin, clams were found to be devoid of this vitamin. Tests conducted on samples of clams obtained from different places and at different seasons, and also on different species, gave invariably negative results. As a source of vitamin A, clams were found somewhat inferior to oysters. On the other hand, they have more pronounced antirachitic properties and are a better source of vitamin E.

Work done at the University of Wisconsin has showed that canned oysters, a product available in most markets throughout the year, contain vitamin D in appreciable quantity.

LAW AS A SCIENCE

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It would seem socially desirable, from one point of view, to have a system of law so certain and rigid that it could be applied to any conceivable situation with mathematical precision and accuracy. Then the legal consequences of particular conduct could always be known in advance. This would seem desirable so that people in the usual and comparatively simple situations may know what to expect of others, how to conduct themselves toward others and how to manage their business affairs without getting into legal difficulties. In more complicated situations under such a system, if laymen should become nonplussed, lawyers would be able to advise them as to the proper course to pursue, and would be able to predict with accuracy the outcome of litigation.

Any person who comes upon my land without permission and cuts down my trees is liable to me in damages. That rule is fairly certain. It applies equally to all people. The rule is known and, therefore, most people do not do such things. If it is not known generally, lawyers can advise as to the consequences of such an act. One of the techniques of our legal system for assuring this certainty and uniformity in legal rule is that known as *stare decisis* or the requirement that courts follow precedent. This principle puts a certain compulsion upon a judge to decide a particular case in the same way that similar cases have been decided before. It is more likely to assure certainty and uniformity than is a rule of action which permits each judge to decide for himself what should be done in the particular case. Different courts, in different localities and at different times having different ideas as to justice would in all probability reach different results on the same set of facts. To the extent therefore that legal rules are certain, impartiality and uniformity are promoted.

Suppose after a long line of decisions holding that removing another's trees without permission is unlawful, a judge with communistic leanings, influenced by the unequal division of wealth and impressed with the dire need of the particular trespasser for fire-wood for his freezing family, should exonerate the trespasser, what happens to the certainty of the rule? Can one now predict that under the circumstances of a particular case the old rule will stand? If one change in circumstances will break down the rule, who can say when another will not? Will not those who desire the trees of another be encouraged to help themselves? Will not increased litigation result from the increased number of such offenses, and from the lack of sureness as to what the outcome will be? Will not socialistically minded judges, with the disintegration of the rule begun, be encouraged to break down the rule further, perhaps for less justification? At any rate is it not probable that all the advantages of having a certain invariable rule on this point will now be lost? Assuredly lawyers can not now safely advise one as to his rights in such matters. Litigation will be much more of a hazard.

Laymen are wont to complain of the law when lawyers are unable to advise them definitely as to their legal rights, and yet they are extremely impatient of the doctrine which requires the following of precedent. They say that each

case ought to be decided on its own merits, or that the judge ought not to let precedent force an unjust result. Yet what could be more destructive of certainty of a rule than the failure or refusal of a court to follow a rule previously established by a long line of decisions? It is too frequently not realized that to the extent that there is a departure from precedent there is a sacrifice of certainty.

Much can therefore be said for certainty of legal rule and as one might expect there is a school of thought which advocates certainty as the most essential element in a legal system. The advocates of this theory might be called rationalists, since they believe all legal phenomena can be rationalized or systematized. By some of this school it is even thought that there is something of the divine in the arrangement of the legal firmament, and therefore a particular decision can be said to be sound or unsound, depending upon its conformity or non-conformity to the divine plan. They think to the extent that there exist doubts, differences of opinion or inconsistencies they are due to the judges' inability to discover or apply the law. The rules are there as an omnipresence in the sky, wanting but an intelligence adequate to recognize and apply them. The judge has but to cast about for the correct rule, bring it down and fit it to the case at hand and justice springs forth, pure and undefiled. Most laymen follow this philosophy. They look upon law as consisting of a set of precise and definite rules sufficiently comprehensive to cover almost any conceivable situation that might arise, and think that all a lawyer need do when asked a question is to open a book and run his finger down the page until it falls upon the rule covering the situation at hand. By then reading the rule he is able to tell his client exactly what his rights are, or what would be the outcome if action were brought.

But alas, do we have, or is it possible or desirable to have a legal system so certain, so rigid? Is it not simply an illusion? If our legal system is certain, rigid, unbending, how is it to grow or adapt itself to changing conditions? Obviously, there must be a limit to its rigidity. Must not rules bend when by a newer conception of morality they work repeated injustice? Must they not yield to a changing economic and social order? When looked at from this point of view it seems obvious that a legal system should be elastic, that is, rules should not be held to be unerring implements to be rigorously and relentlessly applied in all cases regardless of consequences. New circumstances, changing social or economic conditions may require a new or modified rule. But elasticity of rule is inconsistent with certainty of rule. Advantages of certainty of legal rule can be demonstrated. Advantages of elasticity of legal rule can be shown. One makes for stability, the other for progress, but how can a rule be both rigid and elastic? Here is the great paradox of legal science. Most of the difficulties of the law, most differences of opinion about principles revolve about this paradox. To what extent should a rule be certain? To what extent should it be elastic? If a rule results in injustice in a particular case, should the rule always yield to the exigencies of the occasion and a decision based upon the merits rendered?

Of late the traditional conception of law as consisting of a body of fixed invariable rules has been losing ground. During the last half dozen years legal philosophy has been in a ferment. I think the cause is traceable directly to the revolution that has taken place in the physical and mathematical sciences. The development of non-Euclidean geometry, Einstein's theory of relativity, the research of Heisenberg and Schrödinger on the structure of the atom, Fitzgerald's theory of contraction, Comp-

ton's work with electrons, protons and photons, I understand have modified if not demolished orthodox conceptions and principles in physics and astronomy. I am not informed that the physics of Newton has become completely obsolete, but his law that every body continues in its state of rest, or of uniform motion in a straight line, can be readily seen to have lost much of its vitality when we are told that no body is at rest, and that there is no such thing as a straight line.

As bearing upon the significance of recent scientific developments, Professor A. S. Eddington says: "The frank realization that physical science is concerned with a world of shadows is one of the most significant of recent advances.[1] . . . The modern scientific theories have broken away from the common standpoint which identifies the real with the concrete. I think we might go so far as to say that time is more typical of physical reality than matter."[2] And Bertrand Russell says, "The main point for the philosopher in the modern theory is the disappearance of matter as a 'thing.' It has been replaced by emanations from a locality—the sort of influences that characterize haunted rooms in ghost stories. . . . All sorts of *events* happen in the physical world, but tables and chairs, the sun and moon and even our daily bread, have become pale abstractions, mere laws exhibited in the succession of *events* which radiate from certain regions."[3] "In a word 'matter' has become no more than a convenient shorthand for stating certain causal laws concerning events."[4]

The point we are interested in is that physical laws once thought to be universal or immutable have been found to be limited in scope, transitory in nature or based upon erroneous assumptions.

[1] "The Nature of the Physical World," p. xv, 1929.
[2] *Ibid.*, p. 275.
[3] "Philosophy," p. 106, 1927.
[4] *Ibid.*, p. 280.

If principles of the physical world are unstable and transitory things, how much more are principles of the social world, where we deal to a greater extent with human conduct, will, motive, instincts and emotions. Can there then be a science of law?

This tearing down of long-standing physical laws has made many doubt whether laws, physical or social, have any place at all in nature. Perhaps they are mere devices of the mind to make the world about us comprehensible. Perhaps but for the mind of man there would be no laws of nature. One is reminded of the old question—Is there sound if there is no ear to hear?

A group of legal scholars began to fall under the influence of such philosophers and scientists as Eddington, Russell, Dewey, Whitehead and others, and the idea occurred to them that if long-established principles of physics and astronomy have gone to pot, maybe some of the moss-backed legal principles were not as stable as supposed. As a result there came forth a new philosophy of law known as legal realism, which has all but relegated to the scrap heap the entire collection of legal rules found in the books. Although most of its sponsors are to be found among members of law school faculties, its most untempered exponent is Jerome Frank, a New York practising lawyer, whose book, "The Law and the Modern Mind," is only short of sensational. If the so-called immutable laws of physics proved vulnerable to the attacks of Einstein and the modern physicists, how much more vulnerable were the comparatively insecure principles of law to the attacks of the new realists! Under their inexorable logic, venerable rules toppled over like tenpins.

This new school of realism attacks the validity and utility of systematic arrangement of legal phenomena in the form of legal principles. They deny that

such an arrangement appreciably aids in predicting legal decisions. In formulating their creed they draw not only upon the science of Einstein, the philosophy of Dewey, but also upon the modern psychologists. As I understand it there are two phases of their thesis:

First, they deny that objective facts which have to do with legal controversy can be definitely ascertained or set forth and therefore can not be the basis for the application of set rules, assuming there to be rules.

Second, that as to any group of facts which a judge or jury conceives to exist, there is no inevitably applicable rule of law. In other words, the judge has such a choice of so-called principles or formulae of words that he can first reach any result he desires and afterwards find an applicable formula. It is impossible, therefore, to predict a result in any particular case by consideration of the facts and by a study of so-called principles of law, because the facts are objectively unascertainable, and a rule of law can be found to suit any purpose or reach any result the judge desires. The decision is really determined, say the realists, by extra-legal factors, such as the judge's education, race, religion, economic status and bias, psychological inhibitions, or repressions, political considerations, etc., etc.

Suppose we now give a more careful consideration to these two angles of the realists' philosophy.

(1) Impossibility of the Ascertainment of the Facts

Ascertainment of facts, whether physical or social, involves the phenomena observed (*i.e.*, the objective) and the observer (*i.e.*, the subjective). The first is the origin of a stimulus and the second conveys and mentally records it. The result depends as much upon one as upon the other. Modern scientists recognize the importance of keeping in mind these two elements in fact finding. One of the reasons for the inaccuracy of old principles of physics was that facts differ with different observers, as well as with different objective phenomena. The theory of relativity, I am informed, involves the view that things do not just happen, but that they happen as they are observed to happen.

Suppose an automobile accident or some other event has occurred which gives rise to a dispute between two or more persons. There are a half-dozen witnesses. A controversy develops as to fault and as to a basis of settlement. X, one of the participants, consults his lawyer, and states the facts as he conceives them. But is X's impression or understanding of the facts an accurate picture of what actually happened? The facts can be made known to the lawyer only after passing through the senses of X and other witnesses whom the lawyer might call, and the various impressions of these witnesses may be entirely different. Experiments have shown that rarely do two or more witnesses see things alike. They will observe things that did not happen, or fail to observe things that did happen.

The variation in the mental picture of the several witnesses may be due to such things as:

(1) Defect in sight or hearing.

(2) The emotional state of the witness, and this in turn may have been determined by what the witness had for breakfast, how late he was out the night before, or even the amount of secretion of the various glands of his body.

(3) The witness's private or subjective sense of value and his ethical and moral views. His mind will draw colored inferences from the facts in spite of himself.

(4) The witness's own race differing from the race of others involved. He may have a strong prejudice against the colored race or the Jewish race.

(5) The extent and character of his education (for example, if he is an engineer he would see things others would not see), social class, economic and political background, affection or animosity towards particular individuals or groups they represent (*e.g.*, plumbers, labor unions, auto mechanics).

(6) If the controversy involves domestic relations, or matters of sex, the witness's attitude may be colored by his own experience in such matters. His own past may have created abnormal reactions to women or blonde women or men with Van Dykes or Southerners, Italians, ministers, college professors, Democrats.

(7) Childhood inhibitions or conditions, *e.g.*, a certain nasal twang in speech or cough may recall painful or pleasant memories.

(8) His power of recollection may be feeble or may be influenced by others to whom he has talked after the event. A story grows with repetition.

(9) Desire to state what his lawyer wants may have its influence and some lawyers have a way of letting a client know what facts are most favorable to his case.

(10) A witness, too, is bound to make inferences, deductions, and fill in the gaps of his memory.

(11) Then there is sometimes the very potent influence of bribery or other inducements to dishonesty or perjury.

If by reason of all or some of these various influences the picture in the mind of the witness is warped, how much more is the picture in the lawyer's mind distorted when he does not even have the advantage of directly sensing the phenomena with his own eyes and ears but must accept a second-hand, inaccurate description of a picture already distorted in the minds of the witnesses. The result is a grosser distortion in the mind of the lawyer. Now upon the basis of this twisted picture the lawyer is asked to make a prediction of what a judge would say are the rights of the parties when it can not be known what sort of a warped impression the judge himself will have as a result of a trial.

But the lawyer hazards some sort of a guess as to the rights of the parties and a trial follows. Now the trial court will be confronted with more or less or different witnesses than those conferred with by the lawyer. There will be many conflicts and inconsistencies in the evidence. Their testimony will be influenced in various ways by the psychological and economic factors that have been related, and the net effect in the mind of the judge as to the facts is likely to be far different from that in the mind of the lawyer. Furthermore, who can predict the effect of the judge's likes or dislikes as to the lawyers or parties in the case, his economic bias, racial or religious prejudice or other leanings or antipathies. Some contend that his decision may even depend upon what he has eaten for breakfast; hence the term gastronomical jurisprudence, which has been given to this school of thought. Are not all the diverting factors that warp a witness's impressions of the facts likely also to warp the judge's? If the dispute is between capital and labor, who can say how much his opinion will be determined by his bias for or against labor? If the question relates to domestic issues, how much will his decision be controlled by his personal feeling about marriage and divorce, sex conduct, etc.? How much weight will such as the following factors have—that one of the parties is a Jew, is a Catholic, is a Republican, a communist, is wealthy, wears a diamond stud, was born on a farm, is uneducated? It must be remembered that every case involves the making of innumerable inferences and deductions first by the witness himself, then by the lawyer in the case, and then by the judge and jury. The factors

enumerated are especially influential in these inferences. The judge, although not a witness of the facts giving rise to the dispute, is a witness of what transpires in the court room. He is a witness of what the witnesses say and how they say it. All the limitations of a witness and many more limit the judge, because many wills, emotions, prejudices lie between him and the first-hand facts. If the case is tried by a jury, their biases, racial feelings, economic status, likes and dislikes, etc., all influence their compromise verdict and complicate the situation manifold.

As Jerome Frank has put it:

> The "facts," as we have seen, may be crucial when, as is often the case, a question of "fact" is injected into litigation involving a fee-simple. And those facts are, *inter alia*, a function of the attention of the judge. Certain kinds of witnesses may arouse his attention more than others. Or may arouse his antipathies or win his sympathy. The "facts," it must never be overlooked, are not objective. They are what the judge thinks they are. And what he thinks they are depends on what he hears and sees as the witnesses testify—which may not be—often is not—what another judge would hear and see. Assume ("fictionally") the most complete rigidity of the rules relating to commercial transactions; assume ("fictionally") that decisions are products of fixed rules applied to the facts. Still, since those "facts" are only what the judge thinks they are, the decision will vary with the judge's apprehension of the facts.[5]

Without at this time giving any consideration to the law at all (which according to this school of thought can be applied in such a way as to reach any result desired) is it not practically impossible for a lawyer with a distorted impression of the facts to predict what sort of a warped impression of the facts will be made upon a judge's mind by a group of witnesses with a great variety of distorted and inaccurate impressions? And if a judge's decision is hard to predict, how much more hazardous is the verdict of a jury of twelve men?

[5] "Are Judges Human?" *U. of Pa. L. Rev.* 80: 35, 1931.

But the gauntlet of the lawyer's guess has not yet been run. His prediction is not merely based upon what a trial court will do. After all, the appellate court is the ultimate arbiter and the body that lays down the law upon which predictions are based. What further transformation and distortion will the case go through before it reaches this ultimate tribunal? This court does not even see the witnesses or hear their voices. They examine only the printed page. How inadequately it speaks. How remote it seems from the real facts. More than ever, inferences must be drawn to fill out the picture. But these judges have other leanings, biases, prejudices. To what extent do these color the interpretation of the facts, not to mention the application of the law to the facts? Does the ultimate picture in the mind of this court even remotely resemble the true facts as they actually occurred? After all, can the lawyer's advice as to the rights of the parties be any more than a guess?

(2) Difficulty of the Application of Principles of Law

If witness, lawyer, trial judge or jury, and appellate judge have different conceptions as to the facts in a case, how can there be any agreement as to applicable legal principle, assuming there to be such? Principle can have no existence apart from facts. It has meaning only if tied up with concrete phenomena. But if people have different mental pictures as to the external phenomena correspondingly will the meaning of a principle vary from person to person? But a principle is a principle only in so far as it is to some extent general and compelling as it is carried from one group of facts to another, and used by one person and then another, thereby creating uniformity in application. There can be no uniformity and therefore no principle where mental pictures differ as to the facts to which the principle is to apply.

For this reason principles, if they may be called such, overlap and conflict. They are not mutually exclusive. Where there is overlapping or where two conflicting principles seem equally applicable, what is to be the result? The supposed traditional method of a court's reasoning is that the judge first discovers a general principle which covers the case in hand. Then, using this as a major premise and the particular case as a minor premise, the decision is deduced. But that this is not really what a court does may be illustrated as follows: It is a principle of law that in the absence of fraud or coercion persons of full age and of sound mind are free to contract and manage their business in their own way. Another principle is that unfair competition is unlawful. Suppose X, a manufacturer, sells his commodities (say radios) to B and other retailers throughout the country and requires each of them to agree (*i.e.*, contract) not to handle the radios of Y, or any other of X's competitors. Y complains that X's conduct is harmful to Y's business. Now if a judge wants to reach one result he may state his syllogism in this way:

In the absence of fraud or coercion people of full age and of sound mind are free to contract and manage their own business in their own way.

This transaction was free of fraud and coercion and X and B were of full age and sound mind.

Therefore, X and B should be permitted to contract that B shall not use any of Y's radios, and their contract is valid.

Or if he wants to reach the other result he may say:

Unfair competition is unlawful. For X to require B to agree not to handle the commodities of Y is unfair competition as against Y.

Therefore, the contract between X and B is unlawful and invalid.

Each of these principles seems equally applicable to the facts. Why should one be used rather than the other? The question after all is what influences operate on the judge's mind in causing him to select one major premise rather than the other. Would it not be his economic beliefs on the advantages of competition as compared to communism, or some other economic system, or upon his belief as to governmental paternalism as compared with a doctrine of laissez-faire? Since the factors which would influence a judge to select one or the other principle as his major premise can not be told in advance, his decision can not be predicted. If principle, so called, can be selected, narrowed or broadened to suit the judge's desires or purposes, or if the statement of principle is simply a rationalization of a conclusion previously reached by intuition, or by "hunch" or by other extra-legal process, can principle be any basis for predicting a particular judicial result? It should be noted here that after the judge has reached his conclusion by some intuitive or "feeling" process, he proceeds to write an opinion wherein he makes it appear that his conclusion was deduced from legal principles. He frequently does not tell why he selected the particular major premise in his syllogism, which after all is the real key to his decision. The assigned reasons are not the real reasons. Should the assigned, but unreal postulates be regarded as of any value as principles for future decisions?

A further objection to deductive logic as a legal technique is, according to the newer thought, that it is impotent as a device of discovery. Nothing that was unknown before can be revealed by a syllogism. Herman Oliphant in his introduction to Rueff's "From the Physical to the Social Sciences" puts it thus: "If the major premise does not include the case to be decided, it is powerless to produce and determine a decision of it." But, on the other hand, if the major

premise "is taken to include the case to be decided, it assumes the very thing that is supposed to be up for decision."[6] In either case the principle or major premise solves nothing. The syllogism, therefore, is sterile as a judicial technique.

So even if facts could be definitely and certainly ascertained (which they can not be) inevitable and exclusive principle could not be applied so as to compel or force a predictable result. Law, therefore, can not be schematized or set forth by systematic arrangement of rules. To attempt it is simply to bring an illusion of certainty. Courts "feel," "sense" or by some process of intuition or imagination reach their conclusions. They then rationalize, classify and fit into their conception of the legal system that result. The point is that the rationalization does not produce the result, but the result produces the rationalization.

So much for the new realism. Is it to be accepted in whole or in part? Is it nearer the truth than the old rationalistic point of view, which, as has been shown, would make law a comparatively rigid system?

It is my belief that the realists have performed a genuine service in knocking the props from beneath what might be called "rule hero worship." There can be little doubt that lawyers as a class have had and still have too much blind faith in legal rules. If they can but realize that rules are simply arbitrary, artificial legal devices created by the imperfect mind of man in his attempt to comprehend legal facts, and do not constitute a universal, inevitable, perfect or infallible system to be inexorably applied, the legal atmosphere would be clarified and law would likely become a surer instrument of justice.

I have a feeling, however, that although what the realists say is true, they have erred in emphasis on one side, just as the older school erred in emphasis on the other side. Their error lies in not realizing or at any rate not pointing out the relative weight in the whole legal scheme of things, of the matters about which they talk. This overemphasis is no doubt pardonable during the pioneering period but becomes misleading in philosophic summations or appraisals.

It is believed that a more accurate and helpful view lies somewhere between the two extreme positions that have been stated. It is submitted that there is a large part of the law that is fairly definite and certain, and that it should be; that in that part, rules, imperfect as they are, do control, direct and inform lawyers and laymen as to how to conduct themselves; that by reason of the existence of rules many disputes are settled without the necessity of litigation. Legal rules serve as guides to business men, property owners and professional men in their relations with each other. And, perhaps by reason of rules, the great bulk of legal business of the country never gets into court. It is only the doubtful or border-line cases that cause fights. But even in the doubtful cases legal rules serve as sign posts; they point the way to solution by narrowing the issue involved and by bringing to bear upon the question the pertinent considerations. It can not be denied that there are many extra-legal influences in the decisional process, but it is believed that in this process previous legal pronouncement and schematic formulation also weigh heavily with most judges. In spite of the insistence of the realists, rules of one kind or another will and should continue to play a most important part in legal thought and action.

Are there not cases where the preservation of the integrity of a rule, despite a particular result which on its merits may seem unjust, is worth more than a presently just result purchased at the

[6] Rueff, "From the Physical to the Social Sciences," p. xix, 1929.

price of the integrity of the rule? Suppose the officers of the law involved in the Lindbergh baby case had agreed not to prosecute the kidnapers in order to assure the safe return of the baby—a desirable end in itself. Would not such conduct have made other babies less safe from kidnapers? Would it not have given to kidnapers generally such encouragement that they would have extended their kidnaping activities? Suppose a poor man negligently injures a rich man to the extent of $1,000. The rule of law is that the injured party may recover his damages from the negligent party. But in this particular case it is a greater hardship for the poor man to be compelled to pay the rich man $1,000 than it would be for the rich man to fail to get the $1,000. Yet is that sufficient reason for denying the application of the usual rule? Suppose A and B make a contract by which A is to pay B $1,000 six months from date for a lot. Before the six months elapse, A loses all his money in a bank failure, the mortgage on his house is foreclosed, and he is let out of his job. It is probably more of a hardship on A to require him to perform his contract than it would be on B to deprive him of the advantages of his bargain. Yet is the justification here sufficient to warrant breaking down the rule that a man should perform his contractual promises? If an offer to contract is sent by post, an acceptance by post is effectual when posted even though delayed or lost. Suppose a letter containing an acceptance of an offer to sell goods is delayed and the offerer, believing his offer to have been declined, sells the goods to another before he receives the acceptance, and upon receipt of the acceptance he immediately sends notice of his action to the offeree, who in the meantime has done nothing in reliance on his acceptance. The equities here weigh pretty heavily in favor of the offerer. But can not a strong case be made out for holding the offerer to his offer? It is socially convenient to know that a letter of acceptance of an offer by post is effectual when posted. Business men can conduct themselves in accordance with this view if they know it is settled. Lawyers can advise against litigation questioning its soundness. The rule will thus promote the settlement of controversies out of court. Despite the injustice in this particular case, it can still be said that when a letter of acceptance is mailed there is a great probability that it will arrive in due course. Only one letter in many thousands goes astray. Rules of law should be made to fit the probable situation, and they should not be weakened by being disregarded in the rare case when some one is inconvenienced. This line of argument seems reinforced by the further consideration that as to what is justice in a particular case is frequently hard to determine. It is frequently a matter upon which reasonable minds would differ. If what is just—what is a proper balancing of equities—is a matter to be left to the court, should it apply its own conception of justice, attempt to determine what is the general opinion of the community, or the opinion of a majority of the judges who have given consideration to similar problems before? If it adopts the latter, it comes very near simply following the rule dictated by precedent. If the judge chooses to part company with the rule, he would probably do so upon the basis of his own opinion as to the justice of the case. Is that result, or the one followed by many other judges most likely to be just? Suppose in the case under consideration a court were to decide for the offerer, would that be a good decision? It would make room for the view in the future that an acceptance is valid when posted even though delayed, if that seems the most equitable result, or unless the offerer has changed his

position. As a result other kinds of cases would be brought, raising the question as to whether the equities favor the offerer. But is the possibility of a different result in a few cases worth the increased litigation necessarily involved?

The idea of the desirability of the certainty of legal rules may be illustrated by the playing of a football game. Imagine such a game played without definite rules determined upon in advance. The players would not know where or how to line up, whether to kick the ball or in what direction to run. The referee would be at a loss as to how to decide disputes. Suppose a referee should decide that no penalty should be inflicted for off-side play when the play resulted in no advantage to the opposing team or when the offender was *provoked* to get off-side by the violent language of his opponent. Such a decision would introduce a great deal of uncertainty and confusion into the play. When was the opponent's language sufficient to provoke? Did the opponent use offensive language? Were not the words really spoken by another than the opponent, etc.? How many touchdowns have been recalled because a ball carrier's teammate was off-side on the play? And yet in many cases it was obvious that the being off-side did not in any way contribute to the making of the touchdown. Still who would argue for a change in the rule because of the unjust result in the particular case? Certainty, uniformity and facility in referees' decisions and the possibility of adjustment to the rule by all players argue for its retention.

Suppose courts did not decide cases by rule. One can imagine that the reformists would then be clamoring for rules so as to expedite the business of the courts. The first thing thought of by a newly organized committee or council which has a great many decisions to render is a body of rules by which it may classify its cases and reduce many of its decisions to rule-of-thumb procedure.

A formulation of a set of legal principles is simply a method of organizing the legal phenomena found in judicial decisions. This is not only desirable; it is indispensable. This is not to say that a particular formulation is sound or true, all others being unsound. No doubt other formulations could be contrived which would produce very similar results, though the differing systems may appear in certain respects conflicting and inconsistent. The test of soundness is simply convenience and utility. To the extent that a system works it is sound.

I have no doubt that an entomologist could classify all insects upon an entirely different basis from that now generally adopted. He could draw his line of cleavage between classes at a different place or in different directions, and such new classification could probably be made as helpful for studying and understanding the insect world as the one now in use. Surely an astronomer could classify the stars in the heavens according to some other plan than the one now used, but how chaotic the heavens would seem without any plan. It must not be overlooked that in both the physical and the social world things do not naturally arrange themselves in classes or in accordance with principle. Such arrangements are simply the devices of the mind which make the external world intelligible and comprehensible. The arrangements are tentative, transitory, imperfect and incomplete. They leave gaps and overlap. Yet if they help to clarify phenomena and make them rational they serve an indispensable purpose.

Any one who criticizes systematic arrangements, because of inconsistency and incompleteness, must necessarily construct another system in his own

mind, whether he outwardly admits it or not. And how long will his new creation remain invulnerable to attack? The self-satisfied air of the critic who pricks only the balloons of others is amusing until the critic's own balloon crumples and falls to earth. Then one is moved to pity. The objection raised here is not of the altogether commendable occupation of balloon bursting but of the satisfied air of the burster.

It is also well to remember that as to many questions presented to courts there can not be given a satisfactory or proved economic reason for deciding one way or the other. That is, the economic considerations may balance each other, economic opinion may be divided, or, what is more frequently true, economic data on the problem are not available and can never be made available. Certainty then becomes the controlling economic consideration and this can be attained only by adhering to the rule.

It seems to me that the extreme realistic position is vulnerable at certain points. To the cry of the realists that facts and not principles determine decisions and that deductive logic is sterile, Morris Cohen in his "Reason and Nature" asks, "What facts?" A mass of unclassified, unrelated facts reveals nothing, means nothing. They must be organized upon some hypothesis or theory. Deduction, says he, is a necessary tool in determining the relevancy of facts to the hypothesis or theory. Cohen would, therefore, object to the realists' attempt to relegate the syllogism to the scrap heap as a futile tool. Even Dewey recognizes the desirability of schematizing the law for the purpose of explanation and as a guide to conduct. He says, "There is a wide gap separating the reasonable proposition that judicial decisions should possess the maximum possible regularity in order to enable persons in planning their conduct to foresee the legal import of their acts, and the absurd, because impossible, proposition that every decision should flow with formal logical necessity from antecedently known premises."[7] . . . "It is most important that rules of law should form as coherent generalized logical systems as possible."[8]

As I have already stated, recent developments in physics and astronomy do not give much encouragement to legal philosophers in developing a system of law that will aid in predicting the legal consequences of a particular course of conduct. If laws dealing with physical things can not be formulated, how much more difficult is it to formulate a system of law dealing with human beings who have wills, emotions and instincts. But it should be noted that the revolution in physics has been wrought in the very large affairs of interstellar spaces and the very small affairs of the atom, which according to Eddington is as porous as the solar system and whose next quantum jump can not be predicted. Things lying between these extremes are least affected; *e.g.*, rules still enable us to predict results in such moderately sized things as our own solar system. On August 11, 1999, it is predicted that there will be a total eclipse of the sun visible at Cornwall, England. This event will involve the relative positions of but three bodies—the sun, moon and earth. I do not know, but would venture a guess that Lloyds would refuse to issue a policy of insurance against the happening of this event. It is possible but so extremely improbable that some kind of a solar cataclysm will prevent, advance or delay this solar affair that the mathematical chances of its coming off within seconds of the scheduled time are probably several thousands to one. Other safe predictions can be made as to what will happen on that day in August, 1999. The chances are almost so great

[7] 10 Corn. L. Q. 25, 1914.
[8] *Ibid.*, p. 19.

as to amount to a certainty that the Mississippi River will not be dry, that 212 degrees F. will still be the boiling point of water under normal conditions, and that steam engines, electric lights and radios will still work. These accurate predictions are made possible by the so-called classical laws of the physical sciences. Perhaps, then, there is a range in the legal field within which prediction of results can be made with probabilities weighing most heavily in favor of its accuracy.

It is the wise judge who can divine where rigidity should end and elasticity begin. But no one has more clearly set forth the relative force of these two opposing magnets than Mr. Justice Cardozo, the most recent appointee to the United States Supreme Court. He says:

> The law has its formulas, and its methods of judging, appropriate to conservation, and its methods and formulas appropriate to change. If we figure stability and progress as opposite poles, then at one pole we have the maxim of *stare decisis* and the method of decision by the tool of a deductive logic; at the other we have the method which subordinates origins to ends. The one emphasizes considerations of uniformity and symmetry, and follows fundamental conceptions to ultimate conclusions. The other gives freer play to considerations of equity and justice, and the value to society of the interests affected.[9]

> There is in each of us a stream of tendency, whether you choose to call it philosophy or not, which gives coherence and direction to thought and action. Judges cannot escape that current any more than other mortals. All their lives, forces which they do not recognize and cannot name, have been tugging at them—inherited instincts, traditional beliefs, acquired convictions; and the resultant is an outlook on life, a conception of social needs, a sense in James's phrase of "the total push and pressure of the cosmos," which, when reasons are nicely balanced, must determine where choice shall fall. In this mental background every problem finds its setting.[10]

> My analysis of the judicial process comes then to this, and little more: logic, and history, and custom, and utility, and the accepted standards of right conduct, are the forces which singly or in combination shape the progress of the law. Which of these forces shall dominate in any case, must depend largely upon the comparative importance or value of the social interests that will be thereby promoted or impaired. One of the most fundamental social interests is that law shall be uniform and impartial. There must be nothing in its action that savors of prejudice or favor or even arbitrary whim or fitfulness. Therefore in the main there shall be adherence to precedent. . . . But symmetrical development may be bought at too high a price. Uniformity ceases to be a good when it becomes uniformity of oppression. The social interest served by symmetry or certainty must then be balanced against the social interest served by equity and fairness or other elements of social welfare. These may enjoin upon the judge the duty of drawing the line at another angle, of staking the path along new courses, of marking a new point of departure from which others who come after him will set out upon their journey. If you ask how he is to know when one interest outweighs another, I can only answer that he must get his knowledge just as the legislator gets it, from experience and study and reflection; in brief, from life itself.[11]

[9] "Paradoxes of Legal Science," p. 8, 1928.

[10] "The Nature of the Judicial Process," p. 12, 1921.

[11] *Ibid.*, p. 112.

THE ORIGINS OF THE FOOD PLANTS OF PUERTO RICO

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PERHAPS no country having a large quota of food plant species has so few dubious factors in their historical perspective as does Puerto Rico. Any country, especially in the tropics, more or less separated from its neighbors, and abounding in economic flora, would be expected to present many puzzles to the investigator searching for the original habitat and the precise source of the individual plant autochthons and immigrants.

The Island, comprising some 3,450 square miles of mountainous surface, and situate about midway of the Antillean Chain, some 4 or 5 degrees below the tropic of Cancer, has at present something over 500 species of food plants—not counting, of course, the hundreds of horticultural varieties. Roughly speaking, the origins of these economies may be grouped under three nearly equally important epochs: the prehistoric—the period from, say, 500 A. D. (when, we presume, the first human inhabitant appeared) to 1500 A. D.; the Spanish Régime—from the latter date to 1898; and the American Occupancy period—from 1899 to date.

Of the half thousand botanical species in evidence, approximately 150 belong in the prehistoric group, about the same number arrived during Spanish occupancy, and the remainder have come in since—very largely during the first "introduction boom" period, from 1902 to 1910, and during the second, from 1923 to 1929. Much still remains to accomplish: at least 200 valuable food-producing plants are as yet unknown to Puerto Rico. Only two other countries, however, vie with this Island in the number of species, cultivated, semi-cultivated and wild, of real value to the consuming public—the Philippine Islands, with at least 300 native food plants; and India, with probably around 300 native and perhaps 200 introduced species. Other Antilles, notably, Cuba, Jamaica, Hispaniola and Trinidad, were about as well supplied in the prehistoric period as was Puerto Rico.

The major part of the prehistoric food-plant introductions came in, obviously, *via* the Lesser Antilles route—from Venezuela up through Trinidad, St. Vincent, Dominica and the Windward Group lying to the east of Puerto Rico. Just how far back this line of migration extended, we may never know. Setting the peak of agriological expansion in the pre-Inca regions—Tiahuanaco, Machu-Picchu, etc.—at around 1000 A. D., it seems probable that no marked movement of crop plants thence, toward the western and southern shores of the Caribbean Sea, could have affected any of the Antillean islands much before 600 A. D. and perhaps not before 1000 A. D. The varietal differentiation of the few major crops in evidence in the Greater Antilles in 1500 A. D. can better be accredited to the splendid agriology of northern South America than to *per se* expansion *in situ;* the yautías, however, are an exception. Fortunately, since the discovery of fossil maize in Peru, it is no longer obligatory to route the entrance of that crop into the Antilles from Yucatan. A pretty theory is that Cuba obtained some or all of her maize from that ad-

jacent peninsula to the leeward, while the other Arawak countries got theirs via the Venezuela-Trinidad route; however, the paucity of prehistoric maize types in the Antillean region indicates that the crop came into the picture rather late, and it seems certain that the crop accompanied cassava thither via the lands along the south side of the Caribbean.

One feature in Arawak agriology must not be lost sight of—those Amerinds were good agriculturists but not very good fighters or explorers. Whether the Caribs or the Arawaks, or some earlier type of Amerinds, are to be credited with introducing into the Antilles such crops as cassava, maize, peanut, pineapple and some of the legumes, opinions may well differ; granting that the piratical and cannibal Caribs did spread more food-plants about the Caribbean regions, it is, however, logical to suppose that they had no good intentions or purposes in that constructive work. They made frequent trips from island to island, starting originally, presumably, from the mainland coast opposite Trinidad; and in their large, unsinkable dugout canoes they carried both fresh and dried provisions: the "head" of an "ananás," carelessly tossed into the seaside scrub during a makeshift feast (on local Arawak flesh, very likely) might readily establish a stand of pineapples there.

The peaceable Arawak farmers seldom dared to till lands in proximity to the seacoast; however, there were a few valleys in Puerto Rico which happened to be protected by swamps or dense forest on the seaside: Yabucoa Valley, in the southeastern part of the Island, was an example. Protected on three sides by mountain ranges, well watered and drained, and shut off from approach from the sea by a mile-wide swamp at the eastern edge, this fertile, alluvial and hill-wash valley was for centuries the scene of perhaps the best agronomy in Boriquen; and the name is in evidence: the mattock-like hoe, called the "*bucoa*," was their principal tillage tool—and the prefix *ya* meant "the place of" or "where": wherefore, *Yabucoa* was the hoe-place—a field of some ten square miles in area, supporting several thousand Arawaks, and an ideal site for the development of a primitive crop industry.

We shall never know much about the details of Arawak agriology: the early Spanish records are exasperatingly meager. The salient points in that picture of prehistoric food-and-shelter problems are, nevertheless, very interesting.

Crops were raised and harvested every month of the year. There were two rainy and two dry seasons, 50 to 75 inches of rainfall, warm or hot weather always, with a light northeasterly or easterly breeze about ten months of the year; clothing, none; shelter, simple—pole *bohios* or huts, one for each family, with leaf or grass thatch. Playgrounds were large, and kept clean. The *bohios* were in small groups—probably no large villages.

The two great root-crops, yuca (probably made up of *ya* and *iuka* or *huka*) and yautía, were their *pièces de résistance*. They were meat-hungry. The few bean-like seeds supplied insufficient proteids. The hutia, a splendid member of the Rodentia, weighing some ten to fifteen pounds and resembling a plump marmot, was their favorite game. Turtles could often be caught on the beach. Manatees abounded in the river mouths and bayous. Fish they caught in cotton-cord and bark-fiber nets—when the seascape was clear. Oil they had from the corozo palm nuts, as well as from the blubber-blanketed manatees and the turtles.

The Boriquen Arawaks, up to the arrival of the Spaniards, had spent most of their inventive efforts on their main

crop, yuca; for some unknown phenological reason the cassavas are exceedingly seasonal: the stem-cuttings (the only propagational material in use) do not sprout well, except at the end of the winter rains, and, while they are not much affected by either rains or droughts during their growing season, they ripen well only during the autumn dry season. Hence the Arawaks in Puerto Rico were constrained to dry the ripe roots just before the winter rainy season, and this *kasabe* served as their chief food for the winter and spring months. In preparing this, their only specially treated raw product, they invented a peculiar sleeve or cylinder of coarse fiber in which the grated or ground wet fecula was pressed to extract the poisonous juice; by suspending this contraption from a hut pole and hanging a heavy weight on the bottom end of the extensible sack the watery juice gradually was squeezed out, to be boiled down into a black, piquant, odorous, highly wholesome concentrate, called *cassareep,* which was used as a sauce—and still is—as a preventer of autolysis, in the famous West Indian "pepper-pot" and in meat sauces of the Worcestershire type. By the way, this yuca squeezer was perhaps the Arawaks' greatest invention in the industrial line, as was the mysterious "stone-collar" in the line of the ceremonial mise en scène.

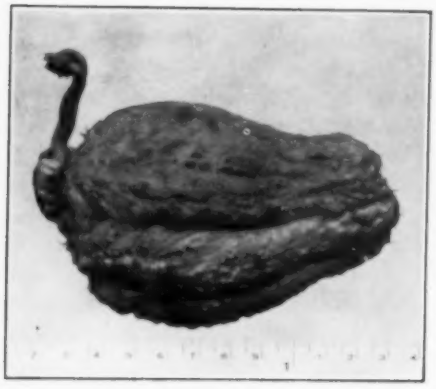
Probably nearly if not quite all the prehistoric varieties (probably 6, perhaps 10) of the yuca in the Boriquen were brought in from Venezuela, via the Lesser Antilles. The species very seldom sports, but very possibly seedling varieties did originate *in loco.* In the present day, some sorts set seed under favorable circumstances; probably, in Arawak days, however, with no open uncultivated ground, no yuca plant was ever left intact beyond its first year; theoretically, *Manihot Manihot* (L.) Coq. is a quasi-perennial—like its wild near relatives. (How often in printed —not written—accounts it appears as "Yucca"!)

The writer believes, with Dr. N. L. Britton, that there is no valid botanical distinction between the "Sweet" and the "Bitter" cassava varieties in any region. The Panamans claim that "any Bitter yuca turns Sweet when grown in Panama."

The second most important food plant of Boriquen was the yautía—taken as a class (like the yucas); and there is little doubt that it was quasi-endemic there. Although several somewhat bizarre varieties were in partial cultivation, at least, in northern South America, Mexico and the entire range of the Antilles, nowhere does the varietal list approach the size of Puerto Rico's.

Of the 39 species of *Xanthosoma* recognized by Engler and Krause, at least 8 and probably 10 are indigenous in Puerto Rico, and 5 of these were cultivated in Arawak times as root crops; undoubtedly several varieties, if not species, in evidence in 1500 A. D., have disappeared within the last four centuries. When the writer began the first yautía survey, in 1902, several of the 15 or more distinct cultural varieties in Puerto Rico were just on the point of extinction. While not quite conclusive, perhaps, the evidence of the complete seedlessness of the cultivated Puerto Rican yautías indicates many centuries of cultivation *in loco.* A remarkable homology is presented by the Oriental taros; like the yautías, they sometimes flower, but probably have never produced seed within historic times. The flowers of both groups are malacophilous —and snails are not very adaptable animals.

With two or three exceptions (in Jamaica, particularly) the Boriquen yautías are superior food plants, as compared with other tropical American varieties. Therefore, we can safely say

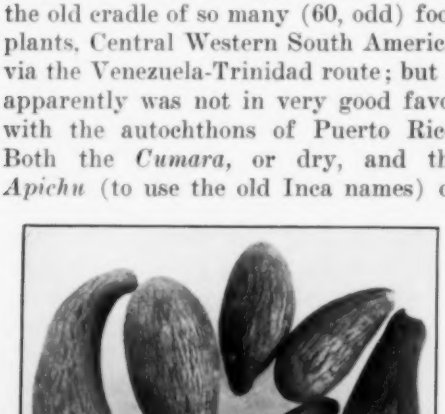


CHAYOTE (*SECHIUM EDULE*)
FRUIT, WITH SPROUT FROM THE SINGLE NON-REMOVABLE SEED.

that Puerto Rico is the home of one of the oldest cultivated root crops.

Two native Belembes (*X. helleborifolium* and *X. brasiliense*) are used as spinach "greens" ("callalous").

Considerable uncertainty surrounds the status of the sweet potato (*Ipomœa Batatas*) in pre-Spanish Boriquen. It must have been brought thither from the old cradle of so many (60, odd) food plants, Central Western South America, via the Venezuela-Trinidad route; but it apparently was not in very good favor with the autochthons of Puerto Rico. Both the *Cumara*, or dry, and the *Apichu* (to use the old Inca names) or moist types, were in evidence, probably far back in the Arawak régime. It is hard to account for the unpopularity of the batata among the farmers of those days; possibly it was a comparatively new arrival. Aside from the breeding of hybrid seedlings, there seems to be little change in the character of this old crop, in historical times.



YAMPEE (*DIOSCOREA TRIFIDA*)
ONE OF THE WORLD'S BEST TABLE ROOTS.

The leren (*Calathea Allouia*) was very likely partially cultivated in the Island for a very long period before 1500. It never seeds. Its excessively long crop period—3 or 4 times that of the batata—must have militated against its general status as a crop. It was apparently of more importance in the Leeward Group—Dominica in particular—and seems to be a West Indian, rather than South American plant.

The two (white and purple) excellent Mapuey yams (*Dioscorea trifida*) were probably brought in before 1500 from South America. Presumably the few inferior indigenous yam species were of little importance in Arawak days; the good ones came with the slaves. Perhaps the "air potato," or gunda (*D. pilosiuscula*), was used as a hunger ration. Its negative feature is its bitterness (of the liver-shaped axillary bulbils), and the positive is its extreme durability. The ripe bulbils from old vines keep a year or more after picking. The dunguey (*D. altissima*) is the largest of the indigenous yams, and could always be found, when needs must, in the denser jungles; it often ascends to the top of the tallest trees and down again.

The teyote, or chayote (*Sechium edule*), appears to have originated as a food crop right in Puerto Rico. More varieties (6 or 8) are found here than anywhere else, and the vine seems happiest here. A 15- or 20-months-old plant may easily attain a length of 100 feet, and may produce a few hundred half-pound to pound fruits. The

starchy but always more or less fiber-filled, irregular-shaped root probably never was popular—and never will be.

There is much doubt about the old sincamas (*Cacara* [*Pachyrhizus*] *tuberosa*) being indigenous in Puerto Rico; the writer is inclined to believe that it arrived before the Spaniards, if not even before the Arawaks. It appears to be, outside of Mexico, an obsolescent root crop, due probably to its tendency to "run to vines" instead of bearing the large, sweet, turnip-like false tubers. We shall never know whether the Arawaks ate its large succulent green pods.

Another mysterious root-crop, which very probably arrived in the pre-Columbian era, is the arracacha (*Arracacia xanthorhiza*); either the Caribs or Arawaks undoubtedly brought it up from Venezuela—the only country where it has, strange to say, ever been popular (in civilized times). Since it apparently never flowers, we infer it has long been a cultigen. The name, of uncertain origin, is applied to several "tubers" of northern South America. Probably none other, of the dozen or more members of the Umbelliferæ which produce edible roots, is so prolific—potentially such a good root-crop; the large, irregular-shaped, odorous root, having the combined flavor of the carrot, celery, parsnip and squash, may be left *in situ* for years—portions being removed from the central "mother" clump as required. It is naturalized in Jamaica (if not indigenous).

Two more root-crops were probably cultivated, more or less, by the Arawaks: the Maranta (*Maranta arundinacea*), or arrowroot, known to the Spaniards as Yuquilla; and the Maraca (*Canna edulis*), or Tulucumá (from which the French devised "tous-les-mois"), or edible canna. Both these crops yield prodigiously under favorable conditions, and to the Amerinds their fibrous roots presented no great problem in starch extraction; and both would appear to be West Indian, rather than South American.

The Arawak fruit foods were fairly numerous. Fruits, however, with the exception of the maméy, were much less important in the dietary than roots.

The maméy (*Mammea americana*: the Latin built upon the Arawak name, rather than upon the shape of the fruit, presumably) was one of the commonest

ROSELLE (*HIBISCUS SABDARIFFA*)
THE PUERTO RICAN "RICO" IN A VARIETY TEST PLAT IN MANILA. (HEIGHT, 4 TO 7 FEET.)

forest trees of Boriquen, and its very large, sweet, pulpy fruits formed, probably, a considerable part of the diet. Not only is the fruiting season very long, but the orange flesh dries readily and keeps well. It probably came nearest to being a really cultivated fruit in the pre-Spanish era.

The jobo (*Spondias Mombin*) was from the very beginning the most common wild fruit; unlike the maméy it is not particular as to soil or location.

These "hog-plum" drupes, pale yellow, an inch long, with a sweetish, slightly turpentiney taste, cover the ground in season under the 40- to 60-foot trees; the autochthons could, in crop time, always count on "filling up" with the mombins, though almost certainly even then the pulp was heavily infested with the (wholesome) maggots of the West Indian fruit-fly.

Around the coast there was always another wild fruit, a dry-pulp drupe larger than the mombin, and either black or whitish—the icaco (*Chrysobalanos Icaco*); the long crop season was a positive factor.

The pineapple (*Ananas Ananas*) was almost certainly a native of Brazil, and very probably the Caribs or Arawaks had purposely or otherwise brought it up to Boriquen some time before the sixteenth century, though it was hardly a food-plant until the Spanish began cultivating it. The autochthons here presumably had no name for it, wherefore the Spaniards applied the name piña—as poor a joke as coco, which the Portuguese gave to the big palm nut from the Orient, with its mouth-and-eye holes, reminding them of the children's "coco," or face mask. By the way, the Portuguese deserve some credit for still keeping the old Amerind name, ananás (accented on the ultima, as usual), for the low-grade, half-wild, tongue-torturing, sour lump of juicy fiber that has developed into one of the four best fruits within but four centuries. And by the same token, how shall we explain the fact that by the time the Americans arrived in Puerto Rico the Spaniards had somehow bred up or "selected" the giant "cabezona," one of the very largest varieties—and the only one ever exceeding 30 pounds in weight?

The jagua or genipap (*Genipa americana*) was probably never very popular, on account of its bad odor and strong taste; but it could "stay hunger" throughout Boriquen forest areas.

The jácana (*Lucuma multiflora*) and the ausubo (*Sideroxylon fœtidissimum*), fairly large forest trees, bore edible fruits, though the pulp was rather scanty. (The Spanish spelling of similar food-plant names is supposed to be based on the names applied by the "Indianos.")

The corozo palm (*Acrocomia aculeata*), known in other Antilles as gru-gru, was the only native palm in use by the Arawaks. Their stone axes were probably seldom used to remove the large "cabbage" or terminal bud—an excellent "salad vegetable," weighing some 10 or 15 pounds apiece; but both the ripe exocarp and the coconut-like endocarp were oily and wholesome.

The delicious níspero (*Sapota Achras* [formerly known as *Achras sapote*]) is supposed to be indigenous throughout the Antilles, but, outside of Central America and Panama, it appears to be a rare tree. A double handful of these russet-skinned fruits made a meal for any native lucky enough to find them: nearly 13 per cent. sugar, with but little waste.

Three or four kinds of murta (*Eugenia floribunda*, *E. axillaris*, etc.) grew here and there over the Island, and were consumed in season.

The cocobola (*Cocolobis uvifera*), which the Spaniards called "Uva de Mar," furnished considerable food in the coastal areas; its grape-like clusters of purplish berries are fair eating.

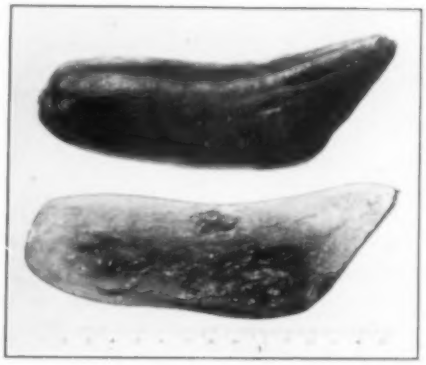
Another littoral tree or large shrub, the pajuil, cajuil or cashew (*Anacardium occidentale*) was probably common all around the Island in olden times; the false-fruit was a good thirst-quencher, if not highly nutritious; it is doubtful whether the Arawaks ever learned how to get the excellent kernel out of the corrosively poisonous shell. Possibly this food-plant was brought up by the Caribs from northern Brazil (or Venezuela), where it has always been known as acajú.

Very probably the cainito or star-apple (*Chrysophyllum Cainito*) was here before the Spaniards arrived—both the green and the purple forms of it; but in modern times it does not appear to be a forest species—as are the three species of caimitillo, of the same genus, with much smaller, but very edible wild fruits.

Opinions may differ, rightly, as to whether the guayaba (*Psidium Guajava*), or guava, is indigenous; the name seems to be Arawak, very significantly; if not strictly native, it might have been brought in either from the south (Brazil) or the west (Cuba and Central America). It was probably semi-cultivated by the Amerinds here—an excellent food species.

Of the far-flung Annonas, we can be sure of but one, the custard-apple (*A. reticulata*)—an important fruit in the more open regions. The Arawak name was probably cayur—also applied to the similar but hardly edible pond-apple (*A. glabra*); but the Spaniards called it corazón—from its shape and size. Quite possibly the two superior sister species (*A. muricata* and *A. squamosa*), the guanábana or sour-sop, and the sweet-sop or hanon (Spanish anón) were indigenous (as the names would indicate).

PAPAYA (*CARICA PAPAYA*)
FEMALE PLANT (ABOUT 9 FEET HIGH AND 1 YEAR OLD).



PAPAYA (*CARICA PAPAYA*)
FRUIT OF THE VERY RARE SEEDLESS VARIETY.

Around the south coast there were three or four pitajayas, cactus fruits of the genera *Hylocereus*, *Leptocereus* and *Harrisia*; these large, or at least, attractive red or yellowish fruits, filled with a sweet, juicy pulp, may have been partially cultivated: what a wonder that the Spaniards kept the name!

The papaya or lechosa (*Carica papaya*) is of very uncertain origin; it was probably not used for food before the Spanish came. One or two native species of Passiflora, especially *P. maliformis*, the curuba, or, as the Puertorriqueños call it, parcha, were of food value to the "indígenas."

The guamá (*Inga laurina*) was probably used by the Arawaks as a forest food plant; the guaba (*I. vera*) may also have filled hungry stomachs in that time.

How mahíz, or maize, reached Boriquen is a problem. Since, with the finding of the famous fossil ear in Peru, we are confident that it originated somewhere south of Panama, and we have

either the Yucatan-Cuba or the Venezuela-Trinidad route—or both—to consider, the writer inclines to the former. Apparently little notice was given by the first Spanish settlers to the giant grass they called maíz (—the "h" being ever a precarious article in Spanish orthography!); but in Quisqueya (Haiti, of the Caribs)—the big island to the west, which he named "Hispaniola"—Columbus found immense fields of this magnificent cereal, the like of which has not been seen in this part of the world since: allowing for travelers' license, the fact remains that his small army had some difficulty in passing through the said vast cornfields of the north-central plain of Santo Domingo.

Whether the Arawaks had learned how to utilize the starch of three poisonous marungueys (*Zamia* spp.), is doubtful; the amount of food contained in the underground short thick stems of these indigenous "coonties" is nearly limitless—the small pockets in the coral limestone hills on both sides of the Island often carrying tons of the raw material per acre.

The bixa, or annatto, or achiote (as the present-day islanders call it), (*Bixa Orellana*) was undoubtedly here before 1500—but used more for body-painting than for food.

The Spaniards were, from the first, imbued with the idea of introducing a great variety of food crops into their newly discovered dominions in the new "India"; and they must be credited with establishing the world's first horticultural experiment station—near Toa Baja on the Plata River, not more than 15 miles west of San Juan, the then "Puerto Rico" of Boriquen (or, as they call it, "Borínquen").

One very questionable account indicates that Colón actually carried a few plants of sugar-cane from the Canary Islands to Hispaniola on his second voyage, in 1493: of course that could hardly have been possible, for it seems to have reached Las Canarias, from Madeira, not until 1503. The writer believes this "honey-bearing reed" arrived in Puerto Rico several years previous to 1520—when the aforementioned Royal Experiment Station on the North Coast was known to have quite a respectable collection of economic plants under propagation for distribution to the eager colonists.

The Spanish authorities, having no experience in plant introduction problems, but with laudable zeal, took over about everything they could lay hands on from the mother country; and when wheat, rye, olives, etc., protested against the tropical heat they blamed the colonists, but finally decided there might be something inimical in the climate, after all.

The four outstanding features of the Spaniards' early efforts at crop transplantation in the Antilles are, in order, sugar-cane, coffee, bananas and coconut.

The so-called "Arabian" coffee reached Boriquen from Hispaniola in 1736; the first Haitian plants were introduced from Martinique in 1735; Martinique had received a few plants, via France, from Java, about 1720. The African, or "Arabian" (*Coffea arabica*), was the only species *en evidence* in the Island, so far as we know, till the American Occupation: over two centuries in arriving, and even then it required another century to put the great industry on its feet.

A Spanish priest, Diego Lorenzo, took the coconut to Puerto Rico from the Cape Verde Islands a little before 1525; and quite likely he took one or more kinds of bananas thither at about the same time; another friar, Tomás de Berlanga, had found, in 1516, the Guanches of Las Canarias (the next archipelago to the north of Cabo Verde) reveling in their new crop, bananas, and no plant

SUGAR-CANE (*SACCHARUM OFFICINALE*)
CENTRAL STEMS (ABOUT 12 FEET) IN FLOWER.

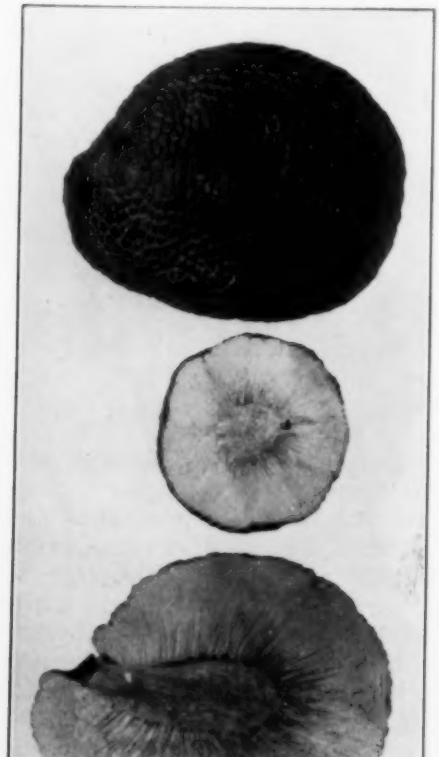
introducer would have neglected to transplant them into the West Indies at first opportunity; in fact, it appears that Berlanga did attempt to take the crop to Hispaniola at about that date. Notwithstanding rumors to the contrary, the writer believes no coconut and no banana, of any sort whatever, was known to any Amerind prior to 1516; what the "plátanos," reputed to be available for victualing ships, up a river on the mainland across from Trinidad, *were* is a great question. And here are other relevant questions: Why have the Puerto Ricans always called bananas "*guineos*" (guineas), instead of keeping their original African (Gulf of Guinea) name "banana" or "bamana"? Why did the Spaniards invent the name "plátano" for certain types of bananas—with not the slightest resemblance to, or connection with, the plátano, or plane-tree (sycamore)? By the way, it is possible that the Arawaks at times ate the coarse rhizomes of the bihai, or pómpano (*Bihai Bihai*)—the wild "ancestor" of the bananas.

Only the ubiquitous green and yellow varieties of coconut were introduced by the Spaniards, in our knowledge. What travelers these two old twin varieties have been for 400 years!—and where did they come from when they started out to cover the tropics, east and west?

The citrus fruits arrived early. Probably the sour orange and citron came first, and the "China," as the Puerto Ricans insist on calling the sweet orange, was distributed to Florida and the West Indian colonies about the middle of the sixteenth century. Another query: Why did the excellent sweet orange, brought around by the Portuguese at the beginning of the sixteenth century, lag behind, by *400 years* or so, the very inferior sour orange introduced by the Arabs, by the overland route, presumably, into the Mediterranean countries?

The lime and the sweet lime came

after the oranges and the citron. The rough lemon, formerly so popular in the Island, is, of course, an immigrant, if not a "sport" *in loco;* but we do not know *what* it is, much less *when* it came. The pomelo, as we should call the grapefruit (*C. paradisi*), is a West Indian upstart, but it probably originated



BREADFRUIT (*ARTOCARPUS INCISA*)
SEEDLESS FRUIT.

somewhere *near* Porto Rico about the end of the nineteenth century, or a little earlier; had any one supposed such a sour, bitter fruit would ever have become a $40,000,000 crop, its birthplace might have been located. Shaddocks (*C. maxima*) were fairly common in the Island on the arrival of the Americans.

The calamondin (*C. mitis*) from the Philippine Islands probably arrived some thirty years ago.

The mango did not reach Boriquen, it appears, till 1740; the good, named, India varieties began to appear here about 1905, when the U. S. Department of Agriculture took up the introduction work in earnest.

The panas, or breadfruits (*Artocarpus incisa* and *A. communis*), arrived in the West Indies from Polynesia in 1793, and probably reached Puerto Rico via Jamaica early in the nineteenth century.

Cacao was introduced from Continental America in 1636; presumably, only the common "Criollo" and "Forastero" sorts were known here before 1903 (when the writer brought in fourteen forms from Trinidad).

Although a wild avocado (*Persea portoricensis*) was discovered in the mountains of Puerto Rico (about 1925), it is certain that the Spanish introduced the common West Indian type, from the westward, probably rather tardily, during their régime. The Guatemalan and the named commercial varieties were brought in by the Americans, of course.

Of the miscellaneous fruits which were brought in during the Spanish régime, the following were of most importance:

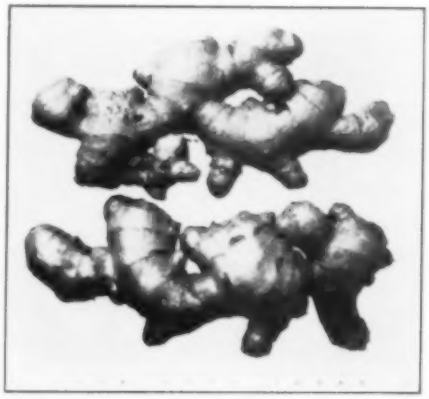
The rose-apple, or pomarosa (*Eugenia Jambos*); early naturalized on the rainy side; the guinep, Spanish lime, or quenepa [perhaps an Amerind name] (*Melicocca bijuga*) may have been brought in before 1500, but seems never to be wild. The grosella (*Cicca disticha*) must have been brought around from the Orient long ago. The granadilla (*Passiflora quadrangularis*), from Central America, has long been widely cultivated—with good reason. The Oriental carambola (*Averrhoa Carambola*)

may have been brought in with the grosella, but is confined to one small district—under the deplorable name "piña." The "tropical almond," or almendro (*Terminalia catappa*) arrived at an uncertain period, probably from the Philippines. Mystery surrounds that excellent fruit, the marmalade plum (a stupid name for a 15- to 25-ounce fruit!), or mamey sapota (*Auiom zapota*, formerly known as *Lucuma mammosa* or *Calocarpum mammosum*); it was almost unknown before the American régime, yet quite possibly indigenous. The hevi, or jobo de la India (*Spondias dulcis*), and the common ciruela, or Spanish plum (*S. purpurea*); the rare jobillo, or ciruela amarilla (*S. ciruella*) is of uncertain origin. The old pomegranate (*Punica granatum*) came early, as, of course, did the olive and date—but they might as well have been left behind, with the peach, pear, apple and plum.

The Indian tamarind was, perhaps, a fellow immigrant with the mango; the very rare sweet variety probably never arrived.

Figs have never been able to long withstand the nematodes.

One of the most important introductions of the Spaniards was the Guinea yam (*Dioscorea rotundata*); it was the *pièce-de-résistance* on the slave ships. Some of the water yams (*D. alata*) may have come across in the same way. Hardly any class of important food plants are more shrouded in mystery as to their origins and early migrations than the yams: the 300 or 400 varieties scattered through the Far East, Middle East, Africa and Tropical America (and so painstakingly studied by Dr. Burkill, the quondam superintendent of the Singapore Botanical Gardens) present exasperating problems to the horticulturist, since many sorts are extremely localized, while many appear "cosmopolitan." The yellow yam (*D. cayen-*

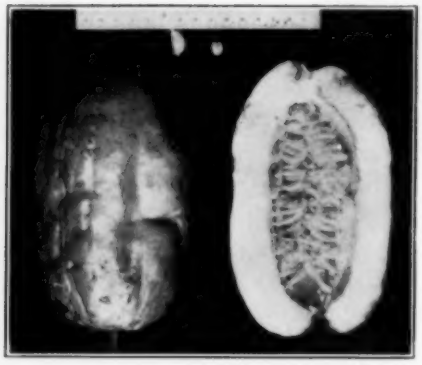


GINGER (*ZINGIBER OFFICINALE*)

"HANDS" WITH "FINGERS" ATTACHED. STEM-BASE SCARS AT LEFT. "HANDS" LIE VERTICAL, 4 TO 6 IN THE HILL.

CACAO (*THEOBROMA CACAO*)

TREE 4 YEARS OLD, BEARING 65 FRUITS. EACH FRUIT (5 TO 7 INCHES LONG) CONTAINS ABOUT 30 "BEANS," WHICH, GROUND, ARE CHOCOLATE.



GRANADILLA (*PASSIFLORA QUADRANGULARIS*)

FRUIT, SHOWING EDIBLE SEED-SACS IN CENTRAL CAVITY.

nensis), the akam (*D. latifolia*), and the potato or papa (*D. esculenta*) are examples *ad hoc*.

The candle-nut, or nuez de la India (*Aleurites moluccana*), was brought in from the Orient or Polynesia long since. The chestnuts and the walnuts did not, of course, succeed; a native walnut (*Juglans jamaicensis*), however, is indigenous in the mountains of west-central Puerto Rico. The true Algarroba (*Ceratonia siliqua*) never has succeeded, but the native tree of the same name (*Hymenæa courbaril*) is a common open-country tree and was probably used by the autochthons for its malodorous but nutritious floury yellow fecula in the large hard-shelled pods.

Ginger, from India, was one of the most profitable crops of the Boriquen colonists in the sixteenth century—in fact, was so popular that a royal edict had to be issued restricting its cultivation (which was threatening the struggling sugar industry here then). Turmeric (*Curcuma longa*), also from the Orient, was here early in the Spanish régime, but probably never used much.

The Iberian vegetables were all tried out, and onions; several beans; okra (or gumbo—both African names, indicative of its origin; known now as guingambó) (*Abelmoschus esculentus*); beets (here called remolacha); carrots; peppers of sorts; lettuce; a few melons; tomatoes; eggplant (locally called berenjena); watercress (*Sisymbrium Nasturtium-aquaticum*), called berros; cabbage; cucumbers; several squashes; radish: all these have behaved as well as could be expected; two varieties of melon seem not to be found elsewhere at present; the hot peppers and okra flourish. Peas, turnips, watermelons, cauliflower, celery, garlic, chick-peas (so greatly relished by all Spaniards), the three kinds of Spanish salsify, spinach and most of the strictly temperate garden truck plants did not do well; yet the record for high-priced watermelons is held here, and spinach is sometimes cropped.

Whence and when the gandul, or pigeon-pea (*Cajan Cajan*), came, no one knows, but it has long been one of the Island's best crops; more "native" and named varieties are in evidence here than anywhere else, probably; the writer believes this valuable forage and food crop originated in the Congo Valley, and that it worked its way up through Egypt, where it became so popular, some 5,000 years ago, that it was put into sarcophagi: strange that only one country has really exploited it—Hawaii, where it probably had existed for years, unrecognized, before the seed for the great crop expansion arrived from Puerto Rico!

Rice has never been a popular crop in Boriquen. But several of the sorghum millets do very well if given a chance. The slave traders were probably accidentally responsible for bringing in Guinea grass (*Panicum maximum*)—as the "bedding" for the poor creatures below decks. That and malojillo (*P. barbinode*) were the two main forage crops in Spanish days; the latter came from South America.

One of the best small grains is

sesame, or ajonjolí; it was formerly quite popular among the "*jíbaros,*" or peasants.

The Spaniards liked well-seasoned dishes, and probably no other country is so well supplied with spice herbs—no less than 45 species being listed in "The Food Plants of Porto Rico."[1] The most interesting one, perhaps, is orégano chiquito (*Lippia helleri*), which was thought to be endemic, but the writer has seen it in markets in Santo Domingo; it "combines all the good qualities of all kitchen herbs." Spanish orégano (*Origanum vulgare*) and the queer, thick-leaved, powerfully aromatic orégano brujo (*Coleus amboinicus*) are excellent species, which should be in every warm garden. Basil, sweet marjoram and rue are fairly common, as are parsley and mint. But sage and caraway apparently awaited American occupation. On a par with the fetid valerian, so popular in olden times, is the culantro del monte (*Eryngium fœtidum*) which does flavor the stews of the *jíbaros.*

The strange, little-known curuba, pepino angolo or cassabanana (*Sicana odorifera*), probably from Brazil (not Angola), has long been seen in all the Island markets, though, like the güiro gourd (*Cucurbita lagenaria*), it is seldom seen growing; it would be of much interest to know where these old cultigens originated.

Vanilla, probably from Mexico, may have arrived before 1900, but was not a commercial crop until very recently.

The gherkin or pepinillo (*Cucumis Anguria*), may be indigenous.

The Himalayan raspberry (*Rubus rosæfolius*), wrongly known in the Island as fresa (strawberry), has long been naturalized in the mountains, and is here one of the few fruits in the world which bear *continuously*: 10 or 15 cents buys a shoe-box full of the beautiful red-caps any day in the year! Some 25 other Rubi have been introduced since 1900, but few do well. The strawberry leads a precarious existence. The rampant (30 feet) zarza, or wild raspberry (*R. florulentus*) is a rare forest dweller.

Spanish grapes seldom bear well, even with careful attention. The parra or wild grape (*Vitis tiliæfolia*, vel *V. caribæa*) is of more value as a stock than food plant.

Whence and when came the malanga (*Caladium Colocasia*), one of the coarser, low-grade varieties of the strictly Oriental and Polynesian taro, we shall never know; it has, however, long been semi-cultivated—gathered from ditches and stream-banks—and is one of the cheapest foods of the jíbaros,

RICE (*ORYZA SATIVA*)
TEN "HEADS" FROM ONE SEED.

[1] "The Food Plants of Porto Rico," by O. W. Barrett; P. R. Department of Agriculture and Labor, 1925.

SESAME, OR AJONJOLÍ (*SESAMUM INDICUM*)

PLANTS (4 TO 6 FEET) IN FLOWER. THE SMALL WHITE, NEARLY HULL-LESS, SEEDS CONTAIN ABOUT 60 PER CENT. EDIBLE OIL.

or "country folk." There were no other taros here before 1900; but in Dominica there was discovered (*sic*) recently a strange taro, called "dasheen de azufre," which had been used by the "natives" of the interior of the Island for an unknown period of time; it seems to have been peculiar to that limited area and to have been cultivated by the "Indians." The occurrence of this cultigen (?) in Dominica, the malanga in Puerto Rico and the dasheen in Trinidad would seem to refute the idea that the taros ("*Colocasia*" spp.) are all paleotropical.

Tobacco (known to the Arawaks as cohiba), a masticatory and not a true food plant, was widely cultivated in the Antilles long before they were "discovered"; it was chewed, "snuffed" and smoked through "tabakos": If we can "drink a glass," can we not smoke a "*tabako*"?

The so-called American introductions are of less agrological interest, from the standpoint of origins, at least. The outstanding features may be briefly set down.

The mangosteen, the "world's best fruit," was brought in from Trinidad Botanical Gardens, in 1903; half a dozen other specimens have arrived since, but the two sturdy and very prolific seedlings, which the writer "nursed

along'' with grave doubts at first for their success, have furnished many descendants since they began fruiting (about 1914). Some seven other Garcinias are here now, some rare species doing well.

One durian, about 12 years old, is in evidence.

Several litchis are promising well. A bulala (*Nephelium mutabile*) from the Philippines is in flower now; one of the best fruits. *Lecythis Zabucajo*, the paradise-nut, brought from Trinidad by the writer in 1924, is a magnificent specimen; and the Amazonian sapucaia (*L. usitata*) was introduced by the Porto Rico Experiment Station.

Of the Citri some 35 species and hybrids, not counting varieties, have been introduced since 1902 (when the Porto Rico Experiment Station was permanently established at Mayagüez); the more important ones are the king (*C. nobilis*), the satsumas and the satsumelos, the three kumquats, limequat, the Chinese Meyer's ''lemon,'' several tangelos, the orangelo, and a fine lot of the little-known Philippine Citri—notably the kalpi (*C. webberi*), the tabog (*Chætospermum glutinosum*), the wampi (*Clausena lansium*), the Davao ''lemon,'' the kabuyao (*C.* [*Papeda*] *hystrix*), the amontay (*C. hystrix* var.), the talamisan (*C. longispina*), etc.

Other rare Philippine fruits of recent arrival are the mabolo (*Diospyros discolor*), the ketembilla (*Dovyalis hebecarpa*), the lanzon (*Lansium domesticum*), the bignay (*Antidesma bunius*), the lemasa (*Artocarpus champedan*), the anonang (*Cordia blancoi*); several Philippine food species have been established 25 years or more—such as the jak (*Artocarpus integrifolia*), the asparagus-pea (*Psophocarpus tetragonolobus*), the Malay-apple (*Jambosa malaccensis*). The Surinam cherry (*Eugenia uniflora*) and the akee (*Blighia sapida*) are not yet appreciated.

A world-wide exchange of seeds, tubers and plants, begun by the Porto Rico Experiment Station in 1902, resulted in amassing a large collection of potential food-producing species. From Africa came the amatungulas (*Arduina bispinosa* and *A. grandiflora*) and the karanda (*A. Carandas*), the cola and a host of *Coffea* species.

The candle-tree (*Parmentiera cerifera*) from Panama is flourishing. The pejibaye, or peach palm (*Gulielma utilis*), arrived from Central America via Washington.

Some 20 varieties of Hawaiian and Oriental bananas and plantains have been introduced since 1902.

The writer had the honor of bringing the dasheen (*Caladium Colocasia esculenta globulifera*) from Trinidad in 1903, but it has not as yet by any means replaced the yautías; it has a shorter crop season, is less particular as to soil, yields better and ''eats'' better—but the *jíbaro* treats it as an interloper. Dr. David Fairchild once said it was perhaps the best single plant introduction —out of some 60,000 numbers—by the U. S. Department of Agriculture. Numerous other dasheens have been introduced to the Island's agriculture since 1902.

The excellent yampees (*Dioscorea trifida*) have been added to the two old varieties of this peculiar dwarf (1 to 2 meters, instead of, say, 10) type of yams; the new ones may produce larger roots but the yield is usually much less certain. Purple yam flour should some day find favor in high-class groceries.

Some 250 sorts of hybrid seedling sweet potatoes were tested in the Insular Department of Agriculture and Labor's Demonstration Farms; some of these (now named) and a few imported varieties are now in cultivation.

In 1924 a practically *always* spineless cactus, the ''semaphore'' (so-called from its long arm-like, horizontal ''pen-

cas") (*Opuntia rubescens inermis*), was found in St. Thomas, American Virgin Islands; a food and fodder plant of merit; propagated by its "*fruits*" (not seeds).

The white sapote (*Casimiroa edulis* and or *C. tetramera*) may become an important new fruit. The voa vanga, or Madagascar tamarind (*Vangueria madagascariensis*), arrived in 1903.

Tea was brought in in 1903 but has never behaved properly. Many new Coffeas and cacao varieties came in through the Governmental Stations from 1903 to 1925. Several vanilla varieties have been added, and one is remarkably productive.

Many European vegetables, especially beans, salads and "kitchen herbs," were introduced between 1923 and 1926. The soya-beans came but have not given satisfaction. Five bonavists (*Dolichos lablab*) were brought from St. Thomas in 1924.

Many tobaccos have recently been tested and distributed; one outstanding hybrid has been created *in loco*—the "ceniza."

The most important forage plants of recent introduction are: elephant grass (*Pennisetum purpureum*), molasses grass (*Melinis minutiflora*), Philippine adlays (*Coix lachryma-jobi*) in variety, and kikuyu (*Pennisetum clandestinum*). Alfalfa rarely succeeds here.

By far the most important crop plant introductions under the American régime have been the new high-grade sugar-cane varieties; these have come largely from Java, but several are locally made hybrids, and a few of much merit from Hawaii, British Honduras, British Guiana and Barbados; some 500 sorts have been tested and many distributed to the 40 "centrals." The famous "uba," which arrived in 1917 from Argentina, virtually saved the industry from the "mosaic disease," but has recently been superseded by the superior Javan hybrids.

Comparatively few introductions have been made since the stringent Federal "Plant Quarantine" was added to the apparently efficient "Insular Service" in 1925, and the present outlook for the entrance of the 200 or more food plants which *should* be brought to Boriquen is deplorably depressing: the rearward perspective illuminant, the forward nebulous.

THE EFFECT OF THE MACHINE AGE ON LABOR

By SUMNER BOYER ELY

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We constantly hear to-day that the labor-saving machine is an economic wrong, that it has been displacing more and more workmen until unemployment has culminated in the present deplorable situation. It is said that the machine has so speeded up industry that overproduction has resulted; and this is believed by many to be the major underlying cause for the present world depression. It is further asserted that the industrial wage-earner in the past constituted the market; now, having lost his purchasing power, our markets have been destroyed; and that if we do not stop inventing we must make some radical change in our methods of distributing wealth. Otherwise the machine will ultimately destroy civilization.

These are severe indictments to bring against the labor-saving machine; and indirectly against science, for the advancement of science made possible the so-called industrial revolution. It is therefore worth while to analyze and investigate these charges in some detail.

The Beginnings of the Industrial Revolution

It is difficult to say just when the industrial revolution had its inception. It is true that the ancient world had a few stones for grinding grain that were driven by a sort of crude water wheel; and it is also true that the genius of Leonardo da Vinci produced some remarkable mechanical contrivances. Yet, what we understand as the industrial age really began with the advent of the power-driven machine tool; some hundred or at most hundred and fifty years ago. It is a strange thing that it is only yesterday in man's civilization that such machines have come into existence. Why they did not develop sooner it is difficult to say. Perhaps we did not possess satisfactory metal or other materials; but whatever the cause was it remained for the later part of the eighteenth century to see the first power-driven machine tools.

Labor Displacement and Adjustment

The old-time shoemaker and his passing is a good illustration of what machines have done to old established trades and industries. In the large shoe manufacturing plants of to-day there is not a man who could make a pair of shoes. Pieces of leather are dropped into various machines, removed and placed together and again put into still other machines, until finally a finished shoe is produced. The shoemaker no longer exists; he is replaced by a machine-tender of little or no skill. There has been what the engineer technically knows as a "transference of skill." The skill possessed by the old shoemaker has been transferred into the machine and the man's skill is no longer required.

But in addition to this transference of skill, the production has been enormously increased and a few unskilled men can now produce as much as a whole community originally. The result of the machine has been twofold, to degrade labor and to require less labor for the same production.

In the early days of the textile industry in England, when automatic machinery was introduced by Jenney, Arkwright and others, the skilled workman found himself displaced by women and children and the cheapest kinds of labor. The scramble for work, the abuse, mis-

ery and terrible suffering that resulted are well known and form a blot on the page of civilization. If a man has spent many years in learning a trade and become highly expert in doing certain things it is not easy for him to discard all this and start anew to acquire another trade. No wonder the skilled man feels bitterly against the machine that has put a boy in his place. Furthermore, his pride will often prevent him doing what he considers inferior work, and at best it is difficult for him to adjust himself to the new conditions. In fact many men never do adjust themselves and it often takes a new generation of workmen before labor can accommodate itself to the new order.

This applies not only to highly skilled labor, but is true to a greater or less extent of all labor, skilled or unskilled. A few years ago, a large steel plant near Pittsburgh, while making certain machinery changes, needed a gang of laborers for a few weeks to pile pig iron. Arrangements were made with a labor agency in Pittsburgh and a car-load of men was sent to the plant. Most of these proved to be Italians who were accustomed to using a pick and shovel. As soon as they saw what was wanted and that they were not to use pick and shovel, most of them refused to work and returned to Pittsburgh. The wages offered were particularly attractive, as the company needed the men badly, and it would seem as if digging with pick and shovel was about as hard physical work as piling pig iron. There seems to be an inertia in labor so that the workman does not easily and freely change from one kind of work to another.

Labor adjustments due to the introduction of machines are taking place about us continually. The reason we do not see or hear much of them is because the industrial field, since the time of Jenney and Arkwright, has grown to such immense proportions. An ordinary improvement in machinery is such a common every-day happening that unless it is of a very spectacular nature it attracts no public attention and goes entirely unnoticed. And yet the effects are always the same, and some workmen are likely to be displaced and forced into other occupations. The very name "labor-saving machinery" indicates that some particular kind of labor is no longer needed.

Machine Production of Wealth and its Effect on Labor

But what about the machine's effect on the general community and its indirect effect on the particular group of men it has displaced? Before 1850 this was a world of deficits, according to one of the officials of the United States Steel Corporation who has compiled some figures on this subject. About all a man could then do was to produce enough to support himself and one other. Today man's productive power has so increased, through the use of machinery, that he can support himself and ten others. This has become a world of surpluses. During our Civil War the machine reaper was invented and first put into use. It solved the food problem for the armies at the time and has made the United States a great exporter of wheat.

Machines have produced goods in such abundance and so cheaply that all classes, including the machine laborer himself, have shared in the general prosperity. Never before in the history of the world have wealth and comfort been so wide-spread and enjoyed by so many different classes of men.

Due to the great growth of industry, which has come about through mechanization, an enormous field has been opened to the workman. Where only a few skilled men could be employed before, now great numbers of unskilled and semi-skilled workmen are in indus-

try. All this opportunity and creation of wealth has raised the whole laboring class, and while a few may have suffered the benefit to the whole has been tremendous.

The laborer of to-day lives better than the lord of yesterday. Properly heated and ventilated living quarters, sanitary plumbing, good food, sewing machines, telephones, electric light are within the reach of nearly every one, to say nothing of automobiles, books, movies, etc. Why, some two hundred years ago, instead of flooding a room with light by turning an electric switch, a smoky torch or at best a spluttering wick was all that was possible.

The cost of living is an indefinite matter and depends on the standard of living, so that comparisons over long periods of years are not satisfactory. It is of interest, however, to see that the United States Department of Labor's index number of the cost of living in the United States doubled from 1914 to 1930, while during the same period the wages in the textile, shoe, lumber and other highly mechanized industries increased some 300 per cent. on the average. The wages of all industries taken as a whole do not show as great an increase as the mechanized industries but, taking into account the cost of living, will average somewhere around 35 per cent. gain for the period 1914 to 1930.

The National Industrial Conference Board surveys show that the volume of products produced in 1914 would have required but seventy per cent. of the number of workmen had the same volume been produced during 1926. Furthermore, the wages would have shown an increase of from 50 per cent. to 100 per cent. and in addition the working day would have been shorter. Such figures indicate that even over a comparatively short period of years there has been an increase in the intrinsic wealth and comfort of the industrial worker.

The Improved Condition of Labor

Along with this physical betterment has come a spiritual release. In ancient times the slave was just so much absolute property, owned body and soul, to be whipped, killed or disposed of as his master saw fit. During the middle ages there may have been a slight improvement in his condition but he was still a serf, and even down to the beginning of the industrial revolution and the start of the factory system labor conditions were very bad. But as the machine developed so did the workman. We do not always remember what an enormous advance labor has made, and that the machine instead of making him a slave has freed him. The machine, too, has relieved him of that terrible physical exertion that a civilization built on slave labor required. The thousands of straining men are no longer necessary to erect a pyramid or a Roman aqueduct. It is often said of the machine that the repetition of the same operation day in and day out makes a workman lose all initiative and responsibility, and that he becomes a mere automaton. Yet it is hard to see why it is more deadening to operate a steam shovel than it is to dig with a hand shovel, or to control a steam hammer than to swing a sledge. A certain job in one of our eastern machine tool shops required a laborer to simply tighten bolts. Even the nuts had been placed on the bolts and all required of him was to draw them up with a wrench. This particular workman had steady work, adequate pay, short hours and a comfortable shop in which to work. If you talked with him you would find that he was not only contented but took a certain sort of pride in how efficient he had become. A man of imagination could not endure such work; but there are many men who prefer something of this kind where there is no tax on their mentality. Perhaps some day we will be able, by psychological or other test,

to sort men and learn for what particular type of work they are fitted.

The Over-production Myth

There is a popular explanation of this present depression which is always advanced during any industrial upset. It is supposed to be conveyed in the high sounding term "over-production." The older economists used to distinguish between the two supposedly antagonistic theories of over-production and under-consumption. We do not hear much of under-consumption to-day. Like that monstrosity, the old economic man, it seems to be dead. Over-production and under-consumption are a mere jangle of words and mean the same thing.

With the advancing machine age and its ever greater production, there seems to be an underlying vague notion that the amount of necessaries, comforts and luxuries which a community can consume is a definite and fixed amount, and that if this be exceeded men will not know how to use the surplus. This is an absurdity. Are there any men who could not easily spend double or triple their incomes? We can own two automobiles as easily as one, we can get a new one every year or every six months. Why cannot a man own ten pairs of shoes as well as one? With houses, clothes, costly foods and what not, any civilized community could double or quadruple its consumption of wealth. What is prosperity but a great increase of luxury, when all the non-essentials such as soda fountains, candy shops and the rest are flourishing?

The fact that during this depression we have too many houses, too much idle capital, storehouses full and men willing and anxious to work means that our economic system is at fault, not that we have produced more than we can consume. If production in one line is carried on until there is an accumulation of vast stocks of unsalable goods we have partial over-production. It may be that this particular industry then thinks best to curtail and men are thrown out of employment, which may disturb the delicate balance of economic relations. It may cause serious trouble; it may not. If it comes at a time when conditions are ripe for a depression it might perhaps precipitate it by giving the initial push. How can anyone say, of this infinitely complex economic system of ours, that any one factor has caused this depression? In the last analysis the depression is psychological and depends on the disposition of people to buy or sell, but the causes which influence this disposition may be legion.

No one doubts that there is such a thing as partial over-production; but this is not the machine's fault, it is due to the bad judgment of the machine's owner and might occur in a non-machine civilization. To condemn the machine because it produces too much would be akin to scrapping all steamships because there has been an occasional accident. Partial over-production there may be, but a general over-production of wealth is an impossibility.

Some Statistics

Is technological unemployment throwing men out of work faster than they can be absorbed in other or new industries? Is the machine destroying the man and forcing him into a permanent bread line?

An examination of the census reports shows that in 1890 the total number of people in continental United States gainfully employed was 36.1 per cent. of the population. By 1930 this number had risen to 39.8 per cent. This includes everybody in all lines: agriculture, industry, business, professional, public and domestic service, etc.

We find that during the ten years from 1920 to 1930, sixteen men left agriculture, four left industry and one min-

ing—a total loss of twenty-one men per thousand of population. Against this, transportation gained seven men, public service gained one, domestic service seven, professional service seven and miscellaneous three—a total gain of twenty-five men. The balance gives a net gain of four per thousand of population. Whatever interpretation we may choose to put on such figures, they at least seem to indicate that employment is increasing faster than population.

Confining our figures now to manufactures only, leaving out agriculture, mining, transportation, public service, fisheries, etc., we find from the census report that forty-two persons per thousand of the population were employed in manufacture in 1850. By 1900 this number had become sixty-three and by 1925 it was seventy-three per thousand population. These figures are perhaps not as definite as we would like, but they indicate, as we would expect, that the United States has become more and more of a manufacturing nation; and that the increase of the number of jobs in manufacturing pursuits has been greater than the increase in the population. If figured out it will be found that the population increased about five times from 1850 to 1925, whereas the number of wage earners, which can roughly be taken as the number of jobs, increased some eight and one half times.

The influence of mechanization on employment is indicated in the following figures obtained from the census. In the shoe industry of the United States in 1900 there were 153,600 persons employed; by 1925 the number was 206,992. During these years when the industry was highly mechanized the number of employees did not become less. Again, in the printing industry, also highly mechanized, in 1900 there were 162,990 persons employed, and in 1925 the number was 251,272. It will be found with most industries, that as mechanization takes place there is an increase in the number of wage earners along with it. These figures may be accounted for by the growth of the industry to meet the demand caused by the cheaper prices that the manufacturer has been able to ask. Then, too, a certain amount of labor is always required, even when mechanized. In some cases machines have been introduced with little or no displacement of men; the effect of the machine being a greatly increased production per man.

What the Future May Bring

Consider for a moment a continuous rod or bar mill in one of our large steel plants. About all the labor required is to manipulate the levers that operate the tables and guide the hot steel billet into the proper rolls, with possibly a little attention when the product comes out of the mill to see that it goes to the proper destination for shipment, storage, etc. In other words the labor is almost nothing and at an irreducible minimum. Mechanization has already reduced the labor so that no more can be saved. In many of our industries we have already reached this point or are fast approaching it. If we keep on mechanizing all our industries, it is only a question of time until we reach a limit.

What is true of labor is true of power. One heat unit can produce 778 foot pounds of work, when completely utilized, and no more. Our boilers to-day are utilizing 80 per cent. or 85 per cent. of the heat supplied to them; which means there is only 15 per cent. or 20 per cent. further improvement possible. Our prime movers also have about the same possibility of advance before reaching the efficiency of the ideal cycle.

Then the law of diminishing returns will retard our advance as we approach the limit. A few years ago when we

were on the top wave of prosperity we heard that there was no restriction on production, that it was possible to speed up the rate of increase higher and higher. The law of diminishing returns was either classed with the economic fallacies of the past or else ignored entirely. Now that we have gotten over the optimism of the boom years and look sanely at the production of wealth, we realize that this law must check us economically as it always has. Every engineer knows how it becomes more and more difficult to increase efficiency, how each saving is a little harder to make than the one before.

Science will progress in the future probably faster than in the past, but so far as labor is concerned science is powerless to reduce what is already reduced. And here is the crux of this whole situation. When we have once become thoroughly mechanized labor can no longer be affected by the machine and must adjust itself as it did before the age of technological unemployment. From this point of view we have made a mountain out of a mole-hill and become unnecessarily disturbed about something that will adjust itself as time goes on.

Of course we can never do without labor as has already been said. There will always be an irreducible minimum. No matter how automatic a machine may be, somebody must start and stop it, see that the right materials are fed to it, oil and adjust it, and a certain amount of attention will always be required. It is quite reasonable to suppose that science may make discoveries and extend our knowledge in ways that are undreamt of to-day, which will bring about the development of a vast number of new machines. Great numbers of old machines will be needed to meet the demand as the population grows. What with the increased numbers of machines in old fields and large numbers of machines in new fields, labor will be provided with great opportunities for employment.

This is only another way of saying that if the census figures are to be believed the number of wage earners will increase faster than the population, probably for many years to come.

SCIENCE SERVICE RADIO TALKS

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INDIVIDUAL DIFFERENCES IN MENTAL GROWTH

By Dr. FRANK N. FREEMAN

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MOST people believe that the precocious child is likely to come to some bad end. If he does not have a complete mental breakdown he at least reaches the end of his development in early youth and falls behind his slower-moving companions before they have arrived at complete maturity. The prevailing opinion of psychologists is just the opposite. According to most psychologists, the child who develops rapidly also continues to develop longer than does the slow-growing child. According to the popular view, the slowness in development is compensated for by a longer continuance of growth. According to the prevailing scientific view, however, the precocious child has a double advantage, and the slower-growing child a double disadvantage. It is very important that we should know which of these views is correct.

It is the business of science to investigate such a difference of opinion as this and to determine which is in accordance with the facts. Since the advent of mental testing, psychologists have studied their results with a view to finding the answer to this and other questions regarding the mental growth of the individual.

Our prediction of the ultimate level of the child's mental ability and the kind of education that we prescribe for the child will be governed by our opinion on the question. If we think, for example, that the child who is developing more slowly in the earlier years is destined to fall farther and farther behind his more precocious schoolmates and to stop developing altogether at an earlier age, we will advise him to take a course which does not demand the same ability and does not extend over so long a period as if we believed that this child might at least keep pace with, if not partly catch up with, his more rapid companion.

Practically all the evidence on this point, which has been available up to the present, has been based upon mass scores from groups of children of different ages. Very few studies have traced the development of the same children from childhood to maturity in order to see what actually becomes of the children at different levels of ability. Certain difficulties arise in the interpretation of the scores from different groups of children at the successive ages which can not be gone into in this brief talk. It is evident, however, that we get a more reliable indication from following the course of development of individual children. This method of study has recently been applied to several hundred children in the elementary and high school of the University of Chicago.

After a period of ten years, a sufficient number of continuous records have been obtained to enable us to throw new light upon some of the problems of individual growth. On the particular problem which I have mentioned, a study of the growth of individual children does not confirm the conclusion from the

earlier studies of mental tests that the slower children reach the end of their mental growth earlier than do the faster children. We are not able to report on mental defectives or even on children of low normal intelligence, but we can compare the growth of those who are somewhat below the average with the growth of bright children. We are able to show, for example, that some children, who get a slow start and are near the bottom of the entire group of pupils in the earlier years of the elementary school, continue to advance steadily well into the college period. In other words, there are some individuals who make a rather low standing during childhood because they get a slow start, but who rise to a higher level in later adolescence because they continue at a steadier pace than some of those who get an early start.

If this were true only of a few isolated examples it would not be of great educational importance, since our educational policies must be based upon the majority rather than upon a few exceptions. In order to find out whether such a case is only an infrequent exception or whether it represents the rule, a grouping was made of about 100 children for whom we had continuous records from eleven to sixteen years of age. We also had records on most of these children at ten years and at seventeen years. This entire group was divided into three groups based upon their scores on the test during the middle years. The average curve for each group was then drawn. These average curves indicate that there is a real difference in the mode of development of the bright and the slower pupils. They also show that the popular opinion concerning the growth of bright and duller children is more nearly right than is the opinion of most psychologists.

The children in the bright group begin to advance at an accelerated rate at about ten years of age. Their curve then advances more steeply for two or three years than do the curves of the other two groups. The curve of these bright children, however, begins to slow down sooner than do those of the others. None of the groups reach their complete development by seventeen years of age, so that it is impossible to say how far apart they will be when their growth reaches its final level. By seventeen years of age, however, the upper curve is slowing up, whereas the lower group of children are continuing to advance at an undiminished rate. This makes it seem certain that the pupils in the lower group will partly catch up with those who took the highest rank during the childhood period.

It would be a mistake to infer from these facts that we are unable to predict at all what the child's later mental attainment will be on the basis of his intelligence or his educational achievement in the elementary school or in the early part of the high school. Such prediction is possible, provided we allow a considerable margin of error and also provided we do not discount the possible future development of the pupils who make a moderate record in the early years. Our findings show that these pupils who are at the middle or even below the middle of their class will continue to advance as long, if not longer, than will the brighter pupils of the class. Some of those who make a relatively poor showing in the earlier years will indeed gain so much on their faster comrades that they will make a decidedly better showing in high school or in college than we might have expected them to make. On the average, of course, pupils in the lower half in the elementary school will remain below in the high school, and few if any of those in the lower quarter are likely to go much beyond the high school; but some pupils in the lower half of their elementary school classes may in the end outstrip other pupils who outshine them considerably during the childhood period.

In our prediction of pupils' later educational attainments and in our advice to them concerning their educational choices, we must make allowances for this fact and we must also give weight to the factors of character and purpose. We have been too inclined to think that the odds are all in favor of the bright and precocious child. We must now recognize that our prediction is not quite so certain as we thought it was and that the slower child may have possibilities of attainment that we have been inclined to deny him in the past.

We could, perhaps, make a more accurate prediction of the course of mental development of children and of the degree of ability they are likely to attain, if we knew more than we do about the conditions which govern such development and ultimate attainment. We know enough to be able to say that development is governed partly by inner forces and partly by outer forces, but we have not been able to measure these inner and outer forces or to say just what proportion they bear to each other.

Some psychologists have thought that mental development is closely bound up with physical development, so that, for example, if a child's body matures early his mind will also mature early, and *vice versa*. If this is true, we ought to be able to use various physical indices, such as growth of teeth, growth of the wrist bones, and signs indicating the onset of puberty, as indicating the proportion of his mental development which an individual child has attained at a particular age. One check on this theory is to compare boys and girls. It is a well-known fact that girls reach physical maturity about two years earlier than do boys. If mental growth follows physical growth girls should attain their full mental stature two years before boys. Some psychologists have believed that this is the case. Our findings, however, do not show that girls reach intellectual maturity any earlier than do boys.

We must distinguish between ability and certain other mental characteristics. There is no question that the girl matures more quickly in her attitudes toward people and in her ability to manage herself in social situations; but this is not the type of mental development I am talking about. I refer rather to what we call intellectual development, or the development of ability to learn and to think, the ability which is required for success in school and college. In this boys and girls seem to advance at the same pace and to continue for the same length of time. If we compare different boys with each other, or different girls with each other, the same thing holds. Those who mature early in body do not mature much sooner in mind than do those who mature late. The difference is so slight that it is hardly noticeable in comparison with the large differences which are due to other causes.

As yet we know very little about what these other causes are. One school of psychologists thinks that they are chiefly or almost entirely internal, that is, that they are a part of the person's inborn or inherited nature. According to this belief, a person's future mental growth is all laid out for him even before he is born and nothing which happens to him, his education or training, his home care, his friendships or his cultural opportunities will affect the course that it will take.

This is an extreme view, and we have good scientific evidence that it is one-sided. We have found, for example, from a study of duplicate or identical twins who have been reared apart, that they differ from each other in ability about twice as much as do identical twins who are reared together. We must conclude, then, that the course of mental growth will be influenced for good or ill by the kind of education the person receives. We can not predict perfectly what mental stature a person will finally

reach or when he will reach it, partly because his growth will be influenced by his training.

These facts are encouraging to the children and to the parents and teachers of children who are not brilliant in their early years. They do not, by any means, indicate that we can make geniuses out of numbskulls, but they do indicate that it is worth while investing educational efforts in pupils who do not seem especially promising, since they may turn out better than their early attainments would lead us to expect.

THE EFFECT OF WORRY ON DIGESTION

By Dr. A. C. IVY

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ONE hundred years ago, Dr. Beaumont, an army surgeon located in northern Michigan, had as a patient a trapper whose name was Alexis St. Martin. The trapper had been shot in the upper abdomen, a hole being made in the stomach. When the wound healed, the opening in the stomach remained open, so that Dr. Beaumont could look into the stomach and see its lining. Dr. Beaumont found that in the presence of fear, anger and whatever disturbs the nervous system, the lining of the stomach loses its healthy appearance and the secretions are greatly decreased or stop flowing. Dr. Beaumont also found that when his patient, Alexis St. Martin, had a quarrel, the movements of the stomach were not normal.

These stories have been duplicated many times in the experience of physicians. Indeed, I am sure that many of you have felt a lump in the throat or beneath the breast bone, when you were grieved over the loss of a friend. This feeling of a lump was due to a spasm of the muscle of the gullet, or esophagus. Or, it may be that when you have been angry or especially worried about something, you felt a lump or pain in the region of the stomach; or it may be that your colon has become more sensitive or irritable than normal. In some people who are particularly sensitive, even the worry or anxiety associated with a business engagement, the making of a speech in public, the fear that a dinner party will not be a success, is sufficient to cause digestive disturbances. I believe that you would like to know why these disturbances occur and whether anything can be done about them.

It is the function of the physiologist to find out the *why* and *how* of such disturbances in the human body and to suggest what should be done to correct them. This, of course, is not always easily and quickly accomplished, because of the complexity of the living body. As a young man, I remember that I visited a great manufacturing plant. I was awed and mystified by what I saw being done. Yet when we realize what wonderful processes occur in our digestive canal, industrial processes are much less awe-inspiring. All kinds of foods enter the digestive canal and are subjected to chemical and physical processes. Digestive juices are secreted which act on the foods in a special way, rendering them capable of being absorbed and of carrying on the processes of life. In a modern industrial plant, each department has a special function to perform. In the digestive system, the stomach, pancreas, liver, small and large intestine have certain functions they must perform. The food is held in one part, the stomach, for example, until its work is completed and is then passed on

to the next part. If these parts do not perform their functions properly, symptoms such as nausea, vomiting, pain, etc., result. If one part does not work properly, the other parts are affected.

All parts of the digestive canal or tube are made up of muscle fibers and glands. The glands secrete digestive juices, or chemical reagents, which liquefy and decompose the food. The muscle fibers churn the food with the digestive juices and move the food along. The muscle fibers and glands are connected with the brain by nerves. The nerves conduct messages to the muscle fibers and glands. In some instances the nerve impulses cause the muscle fibers to contract, in others to relax, or they cause the glands to secrete juice, or they may stop them from secreting juice. Obviously, then, the type of activity going on in the brain may have an influence on the movements of the stomach and intestine and the formation of digestive juices.

In susceptible individuals, only a minor degree of worry or anger may prevent a flow of gastric juice. I shall give two examples. When a hungry dog smells or tastes meat, gastric juice is formed. This is called a psychic secretion. The smelling and tasting of the food excites certain parts of the brain, and nerve messages pass to the stomach and cause it to secrete. If the dog does not like cats, and if we show him a cat, a psychic secretion of gastric juice will not occur. If we start a psychic secretion by permitting the dog to taste meat, and then show him a cat, the secretion will stop. If we teach the dog to like the cat, then we may show the cat to the dog without stopping the psychic secretion. It is difficult, however, to teach some dogs to become accustomed to cats. Similarly, it is difficult for some men and women to learn how not to worry. As the second example, I have in mind a young man who as a boy accidentally swallowed some lye. His gullet or esophagus was burned so badly that it closed up. In order to keep the boy alive, the surgeons made an opening into his stomach through which food could be placed into the stomach. When a young man, he went to a university and said that he would like to serve as an experimental subject. Like the dog described above, when this man tasted and smelled food, much gastric juice was formed. One day he consented to demonstrate this fact to a group of doctors. But he was nervous and excited and the demonstration did not work. He later became accustomed to making public appearances and the demonstration worked every time. It may interest you to learn that if a person is hypnotized and then is told that in front of him on the table is a beefsteak and then he goes through the motions of eating the steak, the stomach of the hypnotized subject "waters" gastric juice just as the mouth "waters" saliva when we actually see a good beefsteak.

The movements of the stomach are likewise influenced by the activity of the brain. Strong emotion may cause a part of the stomach to contract so forcibly that severe pain results, as in the case of the young lady I told you about. But worry generally retards the movements of the stomach and the food may lie in the stomach for a longer time than normal. For example, when one studies the movements of the stomach in cats and dogs, the animals must be handled very gently in order to observe normal movements and emptying of the stomach. Several years ago I observed that when medical students are given a written examination in physiology, the emptying of their stomach is prolonged an hour or more. In this connection, I should point out that the stomach has a front and a back door, so to speak. The foods enter through the front door, and after being partially liquefied, the move-

ments of the stomach force them out through the back door. Now, if the movements of the stomach are not strong and if the back door is closed more tightly than normal, the food will remain in the stomach longer than normal. Also when one is anxious and worried, one is generally not careful how thoroughly the food is chewed, and large lumps of fruit, vegetables and meat are swallowed. Now, when one is worried, the back door of the stomach may be closed tightly and these lumps of food, being difficult to liquefy, may remain in the stomach many hours.

From what you have been told, it is apparent that if the food is appetizing, if the surroundings are pleasant and the frame of mind so that the food can be enjoyed, the digestive organs are prepared or girded for action and function perfectly. So there is much truth in the statement, "Laugh and grow fat; worry and grow thin."

Emotion, anxiety and worry not only affect the movements of the stomach but also movements of the colon. Certain movements of the colon may be stopped and others increased by worry. Worry and nervous tension generally cause the colon to become more irritable and spastic and produce colitis. You all know that the last part of the colon is under the control of the brain to a very large extent, and good and bad habits may be formed in regard to its emptying.

Another interesting and important fact is that hunger is caused by vigorous contractions of the stomach. If one fasts for twelve or twenty-four hours, pains are felt in the region of the stomach which are caused by the vigorous contractions of the stomach. If one is anxious and worried, these contractions may not occur, and appetite is frequently absent. Hunger and appetite increase the rate of digestion and the emptying of the stomach. Some so-called "nervous" children do not eat because they are worried and have been unduly excited by nagging parents or by some story they have heard or some picture they have seen.

It would be wrong for me to give you the impression that anxiety or worry is the cause of all digestive troubles, because it is not. The facts that I have pointed out do show that peace of mind and comfort are very important for normal digestion. These facts also show that mental discord and worry disturb normal digestion and may serve as the background for the development of certain diseases of digestion. In this connection it is a fact that deaths from gastric ulcer have increased 25 per cent. among white men since the start of the depression in 1929. And it is certain that altered physiology of the stomach is very likely concerned in the cause of gastric ulcer. Every physician recommends as a part of the treatment of gastric ulcer and of colitis, diet, rest and freedom from worry, or a vacation.

What is the solution of the problem I have outlined? It would be easy for me to say that the solution is to stop worrying and to avoid things that cause worry, strife and care. But this is impossible for a busy man or woman with responsibilities on his or her shoulders. But I think there is a way out for even the busy man and woman. First, we must teach ourselves to forget our worries and responsibilities for brief periods at least. Every one knows that a sense of responsibility is acquired and may become a habit. I think it is an excellent habit, unless carried so far that we permit it to interfere with our health and the happiness of others. It is good to take oneself seriously, but not so seriously that it interferes with one's health and sense of humor. Now just as we learn or train ourselves to shoulder re-

sponsibilities, we can train ourselves to forget them. Some people say they can not do this. That means only that their "worry habit" is very bad and that it is going to require much effort to conquer it. But it can be done. Second, we must learn how to relax our body muscles at will. The learning to forget to worry for a brief period and to relax the body muscles are processes which are closely associated. When one is worried, the body muscles become tense and may remain tense even when sitting or lying down. The ability to relax and rest for brief periods under any circumstances may be acquired and learned. Fresh air, exercise and non-competitive play assist one to forget and to relax. When we sit down to eat and even for a brief period before and after eating, we should forget our worries and relax our muscles. While eating, we should think of pleasant things, enjoy the food and chew it thoroughly. And third, during a day fraught with business worry, wrangling, mental or nervous strain, or at times when it is impossible to forget and to relax, we must either postpone the meal until strong emotion has passed, fatigue has lessened, calm has been restored and appetite has returned, or we must eat lightly of foods that are easily digested and emptied from the stomach such as soups, cereals, puréed or mashed cooked vegetables, etc., or what physicians call a soft diet. In this connection we must bear in mind the fact that raw milk is changed into a solid in the stomach and that it is better for some people to mix the milk with toast or cereal.

Let us remember that our stomach should be a servant and not a master. We should not spoil it by too much attention, neither should it be ruined by wilful neglect and abuse. "Better is a dry morsel and quietness therewith than a house full of feasting with strife."

GOLD

By SCOTT TURNER

DIRECTOR, UNITED STATES BUREAU OF MINES

PROBABLY the word gold is used more frequently in the language of metaphor than in direct reference to the metal itself. It will be found employed thus many times in almost any book, and it recurs constantly in our daily speech. We refer to a golden age, a golden hour, a golden memory, the golden rule, and to silence that is golden. A golden fleece inspired the Argonauts to adventure; a golden edict granted rights to an oppressed people. There is a golden mean of conduct; the word of an honest man is as good as gold. There are golden voices, opportunities and opinions.

Things are said to be as pure as gold; a voice resembles liquid gold; worthy people have hearts of gold. Many uses of the word refer to its color and metallic luster, as golden sunset, golden hair, golden grain. Thus the word is employed to suggest not only a lustrous yellow metal, but purity, value, worth, merit, perfection, beauty and other similar qualities that indicate the high esteem in which this element has long been held. Yet gold is a metal, as iron, copper, lead, zinc, aluminum and tin are metals. It resembles all of them in a general way, some of them closely; even its color can nearly be matched by brass, a mixture of copper and zinc, or by bronze, a compound of copper and tin.

Why, then, is gold so valuable and so important? Certainly not because it is yellow, heavy, malleable, ductile and lustrous. The explanation is that this

one metal is endowed with a particular combination of properties that made possible its ancient discovery, and led to its early utilization, to wide-spread longing for its possession, and finally to its use as a measure of worth and as a means of storing value for the future.

The human desire that results in gold being so highly prized is as old as history. It has persisted through thousands of years. During perhaps a hundred centuries, while nations rose and fell, as conflicting philosophies, religions and the languages in which they were expressed, waxed and waned, mankind agreed in this at least—every one wanted gold. This desire was paralleled in intensity and persistence only by the craving for food and other necessities of life, for which gold could be exchanged at will.

Throughout the ages, can man have been mistaken in his esteem of gold? Was he infatuated and beguiled by its yellow glitter, though not by the gleam of brass and bronze? Assuredly not. Though he was not aware of the numerous factors that jointly created gold's value, he was competent to judge whether a little gold would serve him as well, or better, for certain purposes, than many times its weight of brass or bronze, and he decided that it would.

One reason for his choice was his observation that, with gold, he could buy not only brass or bronze, but any other commodity, whenever he chose to do so, and that he need not hurry to trade it away, as he did when he invested in perishable commodities or those that cost something to store and keep; gold gave command of time. Man knew that until he decided what should be bought with this gold, he could secrete it or transport it more easily than other commodities of equal worth. In his purse, he could carry enough to pay for all the grain many beasts of burden could carry. Gold was so indestructible that, if buried, it would not rust; even if melted by fire, it would still remain the pure bright metal. If its possessor traveled to a distant land where people spoke an alien tongue, they would nevertheless understand the worth of the gold he offered them in trade.

Gold was more stable in value than other commodities; all others varied more widely and more rapidly in price. Oversupply of many of them, due to seasonal production, was followed by depletion and dearth, because they were gradually consumed. The effect on prices is illustrated by the low cost of grain after harvest and the high price before it, or by the charge for fish after and before an unusual catch. Gold, however, was neither consumed nor supplied in great excess. Withdrawals and returns of gold, from and to circulation, tended to balance in the long run; if its value began to decrease because of oversupply, export of gold to other places, where it would buy more, tended to occur because it was so easily transported.

Hence, its price was fixed less by local than by wide demand, and it was, therefore, more stable in relation to the mean of prices in general. The superior steadiness in the value of gold was naturally prized by the prudent, who were saving for the future and for old age. Just as insurance funds are invested to provide security above all else, so men of the past who wanted a store for future use sought gold in preference to other commodities as the means to this end.

For these and similar reasons, it was not illogical that man used gold long before there was money. It was easily beaten into the desired form, and its softness helped to save it for special purposes, since it was not hard enough to be generally useful and was therefore reserved for ornaments. As its esteem for personal decoration grew, it naturally went from the weaker to the stronger, from the tribesman to the chief, and so it was hoarded and saved.

Almost precisely the same circumstances applied to silver after its discovery, which was later than that of gold; both metals had been employed in barter and trade, as preferred mediums of exchange, long before the first coin was made, and ages before our present monetary systems began to evolve from the use of gold and silver money. At an early date, however, much larger stocks of silver than of gold must have accumulated, because the price of the former appears to have been only a fifth of the price of gold when mining of silver was begun by the Athenians.

The monetary systems of the present have marvelous social utility, but they should not be deemed more remarkable than the automatic evolution of exchange in earlier times through the use of gold and silver, from which financial methods were, in turn, evolved. The early basing of commodity-exchange upon metal was induced by prehistoric man's discovery of so-called placer deposits of gold in stream-beds of Asia, Africa and Europe. Indestructibility and high specific gravity of the metal were important factors. In many such deposits, the gold could be seen readily, as it was in 1848 when discovered in California. Placer gold may occur in tiny flakes or grains, or in nuggets of considerable size. One nugget found in California weighed nearly 1,600 ounces. Another in Australia exceeded 2,000 ounces; it was revealed by the rut made by a wagon wheel. A savage would hardly ignore such a nugget, even though he had no previous knowledge of this metal. Leo Africanus, writing during the Middle Ages of a king who lived on the Gold Coast of Africa, described him as using a huge nugget of gold as a seat.

Gold is identified more readily than other metals, because they usually occur in nature in chemical compounds; the property of gold that keeps it bright and free from tarnish likewise prevents it from passing into solution, and from combining readily with other elements. It is relatively imperishable. That is why it is found concentrated in placers as a bright native metal. Glittering objects catch the eye of animals; gleaming gold must have attracted instantly the attention of primitive man. It is presumed to have been the first metal discovered by human beings, though there are no records to prove it. We only know that gold was already established in use and in the esteem of man when history began.

Two other things about gold have probably been important. It is widely distributed about the earth's surface, as it occurs to some extent in nearly every country. This would tend to make all peoples acquainted with it sufficiently to account for its wide-spread acceptance. The other is the fact that nowhere is gold extremely abundant. Most of the time, before the present century, the increase in accumulated stocks of the metal throughout the world proceeded slowly, and the amount added each year was not sufficient to disturb the value of gold, especially as the addition would tend to be balanced somewhat by growth of population and by expansion of trade. The latter accounts for the ready absorption of enormously expanded production of gold in recent years, without pronounced effects in inflation.

The whole fascinating story of gold, covering its occurrence, discovery, production and use, its influence upon progress and civilization, on history, on the struggle of man to conquer his environment and upon his mind, oriented to gold as a symbol of individual, national and social well-being, concerns an astonishingly small amount of this precious metal. All the gold produced in the world since the discovery of America, which probably exceeds vastly the total in the ages before, could be contained in a cube measuring less than 40 feet on each edge. In weight, this amounts to

only about 38,000 short tons; over fifty times that weight of copper was produced in the single year, 1929.

Think of the work and effort, the rivalry and strife, the injustice and oppression, the schemes and plots, the quarrels and fights, the battles and wars that have been involved in the accumulation and preservation, the winning and owning, of this relatively small amount of yellow metal!

A one-inch cube of gold is worth about $210; if an infantryman in the United States army carried the weight of his standard battle equipment of 71¾ pounds, in gold, he would have $21,600 worth—enough for a cube 4.7 inches on an edge. If you could carry 250 pounds on your back, you might walk away with a little over $75,000 worth of gold, which would make a cube a trifle larger than 7 inches on an edge. If you owned a 9-inch cube of pure gold, you would have over $150,000.

In more than three and one half centuries, from the discovery of America to about 1850, only 151 million ounces of gold had been produced in the entire world; but in the next 82 years, ending with 1932, 959 million ounces, or 6½ times as much, was produced at a rate 28 times as fast. The earlier production came from placer mines or from gold mines that could not be worked far below the surface. Now the amount from placers is small in comparison with that from veins; vein-mines sometimes extend a mile and a half into the earth, this having been made possible by recent technologic advances in the art of mining; the story of the winning of gold is not yet finished.

You might not know that the greatest gold mine in the United States is in South Dakota; it is called the Homestake. Alaska contains the second largest. You would rightly guess that more gold has come from California than any other state. Canada produces more gold than we do; in fact, last year the Province of Ontario alone was the source of more gold than the whole of the United States. The greatest producer in Canada is the Lake Shore mine; the Hollinger stands second. About half of the gold won annually in all the world comes from the Union of South Africa; nearly two hundred and forty million dollars' worth was won there last year. The greatest African mine is called Government Gold, with the Crown mine a close second. Either produces nearly three times as much as our largest mine.

Truly it may be said that there is a golden thread running through the embroidered tapestry of history, from dim prehistoric figures of men trading nuggets, to our own financiers and leaders of industry conducting vast transactions based upon minted gold, but it should not be overlooked that this filament of gold is interwoven throughout with one of silver, and that silver is now employed as the basis of money by Eastern peoples as numerous as those of the West who use gold for the same purpose.

THE WORK OF THE BUREAU OF STANDARDS IN LIGHT AND HEAT

By Dr. CLARENCE A. SKINNER
PHYSICIST, THE NATIONAL BUREAU OF STANDARDS

THE Bureau's activity in light includes: The wave-length measurement and classification of emission and absorption spectra, along with certain extreme phases of chemical analysis for which these are especially applicable; investigation and tests involving measurements of polarized light and its applications, especially in the testing and technology of the sugars; development of methods and measurement of factors which determine color, measurement of the spectral transmissive and reflective properties of materials and the color grading of light sources and materials; development of methods and testing the performance of optical instruments, development of instruments for new types of service and measurement of refractive indices of optical materials; the development and maintenance of basic and working standards of light and photometric testing of illuminants; development of radiometric methods and instruments, development and maintenance of standards of thermal radiation; investigation and sensitometry of photographic emulsions and development of photographic methods; standardization of equipment for producing, controlling and measuring x-radiation, development of methods and measuring the radium content of materials; the application of the interferometer to the accurate measurement of length, including the calibration of end standards and ruling of line scales with light wavelengths as the working standards.

It is interesting that light furnishes the longest and shortest units of length. The light-year, about 250 million times the earth's equatorial circumference, is used for designating the distance of stars; but the accuracy of this unit, equal to that of the measured velocity of light, is not important. On the other hand, the wave-length of the red radiation of cadmium, so short that 100 of them make up a length doubtfully detectable by the unaided eye, is prized for its accuracy, reproducibility, constancy, the facility with which it can be magnified for observation purposes and the range of its application.

The Bureau has contributed extensively to the development and adoption of interference methods in metrology, and has shown through these that precision gage materials are commonly subject to change of length with time. Crystal quartz even does not keep its length accurately in step with its temperature when carried through a moderate temperature cycle of 30° C. Fused quartz (silica glass), on the other hand, with its extremely low thermal expansivity, appears to be ideal material for such purposes. The Bureau has several decimeter end gages of this material now in the final stages of preparation, for calibration by light wave-lengths. By the use of these gages in the different national laboratories, it is hoped to ensure international length standardization to an accuracy of one part in a million. Also, using light waves to step off the intervals, line scales ranging in length from a millimeter to a meter are ruled. These serve as exact master scales in precision establishments where the elimination of the customary correction chart improves greatly both the speed and accuracy of production.

For working standards of length sev-

THE BUREAU'S SELF-CHECKING SET OF OPTICAL PLANES OF FUSED QUARTZ

THE DISKS ARE APPROXIMATELY 11 INCHES IN DIAMETER AND DEVIATE LESS THAN ONE HUNDREDTH OF A WAVE-LENGTH FROM A PERFECT PLANE. THEY ARE THE BUREAU'S BASIC STANDARDS FOR TESTING BOTH THE PLANENESS OR CURVATURE OF SURFACES AND THE PERFECTION OF "STRAIGHT EDGES."

eral hundred wave-lengths of the iron spectrum distributed from 2500 Ångstroms in the ultra-violet to 8500Å in the infra-red have been measured at the Bureau to one part in 2 million or better. These have been adopted as secondary wave-length standards by the International Astronomical Union. A search is now in progress for other wave-lengths, accurate to one part in 20 million or better, which may serve along with the cadmium wave-length as basic standards.

In photometry, the recognized unsatisfactoriness of flame standards led the Bureau several years ago to set up working standards of carbon filament incandescent lamps, rated in candle-power. Extensive comparisons have revealed these to be highly satisfactory, lacking neither in constancy nor durability. They permit photometric measurements accurate to $\frac{1}{4}$ per cent.; where, using flame standards, certification closer than 2 per cent. can not be obtained. Spectrophotometrically standardized optical filters used in conjunction with these incandescent carbon filament standards permit, by eliminating color differences, the accurate candle-power measurement of present-day illuminants.

A primary standard of light, a source accurately reproducible from specification and reasonably near the color of the incandescent carbon filament secondary standards, has been realized at the Bureau relatively recently, in the form of a black body radiator at the temperature of freezing platinum; and its candle-power has been measured.

For the past 20 years the Bureau has also been using and issuing carbon filament lamps as working standards of total radiation, calibrated with the black body radiator as primary standard. These have proved constant over a period of several years and of wholly negligible deterioration with use.

The problem of standards of color is much more complex than that of radiant or luminous power. For example, the color of things, which are not themselves sources of light, depends on the illumination used so that a specification of their color must include a specification of the illuminant. The physical counterpart of, or stimulus evoking color, is in general a mixture of light of different wave-lengths or spectral distribution. The same spectral distribution always evokes the same color sensation, though the same color sensation can be produced by different spectral distributions. Where reproduction of a given color is to be attained through reproduction of the spectral distribution, a spectrophotometric analysis is made. The standardization of railway signal glasses, in which the Bureau is at present engaged, is an important example of this type of color measurement. The Bureau makes also such spectrophotometric tests for the public and issues spectrophotometrically calibrated sets of colored filters, by

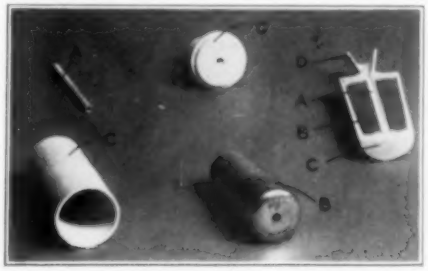
means of which an individual laboratory may check the accuracy of its own spectrophotometer.

For the reproduction of a given color, irrespective of its spectral composition, the Bureau has under way the standardization of a set of 400 colored glasses, which, singly or in combination, will match four fifths of the estimated million different practicable colors—the nearly pure spectral colors not being reproducible by this set. Over one hundred of these glasses, representing colors used in the edible oils industry, have been standardized and graded; and samples, nominally the equivalent of any in this group, are accepted for standardizing.

Relative to the color of illuminants, of which the most important range from the candle to the sun, the Bureau is now preparing to standardize these in terms of the temperature of a black body radiator, "color temperature," which most nearly matches the color of the given source. In this connection, it has also developed a series of optical filters for converting lights of lower color temperatures to various higher color temperatures; and one of these combinations has been adopted as an international standard for photographic sensitometry.

The list of measuring instruments and devices developed in this field by the Bureau includes: Polarimeters, colorimeters, special types of photometer, radiometers, a photographic sensitometer, an optical coincidence gage, optical components for special types of service and interferometers of varied application—the most recent being an instrument for measuring the tilt of the earth's strata which serves as a warning of approaching earthquakes.

In heat one of the important functions is the maintenance and distribution of the temperature scale. The thermodynamic scale, being independent of the properties of any particular material, is an ideal temperature scale; but precise measurement on this has proven to be solely a research laboratory project. For practical purposes, the adoption of secondary scales has been imperative. As a basis for such, the Bureau has used mercury-in-glass and platinum-resistance thermometers, rare metal thermocouples and optical pyrometers—these having the attendant advantages of speed, high degree of precision and reproducibility. Being to some extent arbitrary, however, both as to specifications for calibrating secondary thermometers and as to temperature ranges for which the different types were used, minor differences between laboratories were inevitable. To eliminate them, the Bureau took an active part in negotiations which led in 1927 to the adoption of an international temperature scale by the General Conference of Weights and Measures, representing 31 nations. The international scale is based on six fixed points and precisely defined methods of interpolation between them and extrapolation above the highest. For the interval 0° to 660° C. the platinum resistance thermometer is standard, and the same with a different calibration covers 0° to −190° C.; for 600° to 1063°, the thermocouple of platinum against 90



PLATINUM INGOT, B, AND REFRACTORY PARTS, A, C, D

USED BY THE BUREAU OF STANDARDS IN A RESEARCH TO OBTAIN A SOURCE OF LIGHT SUFFICIENTLY REPRODUCIBLE TO SERVE AS A FUNDAMENTAL PHOTOMETRIC REFERENCE STANDARD. THE BUREAU'S METHOD HAS BEEN PROPOSED FOR INTERNATIONAL ADOPTION AS A PRIMARY STANDARD OF LIGHT.

platinum-10 rhodium is specified. Above 1063°, the freezing-point of gold, the temperature is defined in terms of monochromatic radiation from a black body—without specifying any particular instrument, but theoretically identical with the thermodynamic scale.

Bureau contributions to the development of the methods and instruments, which form the basis of the international scale, are the investigation of the boiling-point of sulphur and freezing-point of silver; the design and construction of resistance thermometers, which have found extensive use; the improvement of methods of preparing platinum and its alloys in a state of purity and the production of thermocouples for testing this purity; and also the development of an optical pyrometer, including technique for precise measurement.

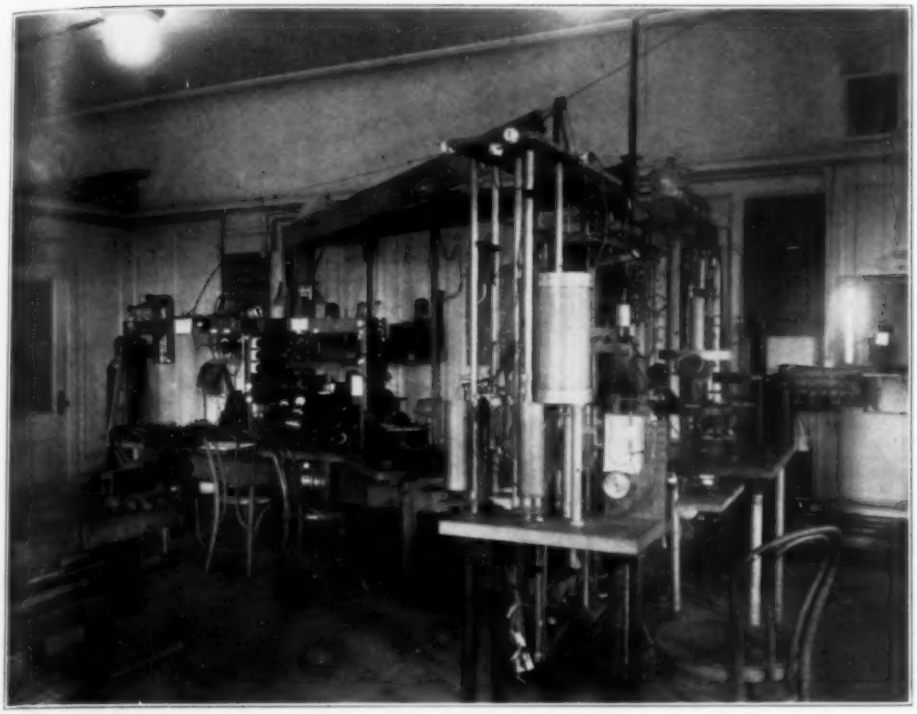
Work in gas thermometry at the Bureau is designed to provide, first, a working scale of temperature below −190° C., the present limit of the standard scale; and second, further basic data in the range now covered by the international scale.

To make an exact temperature scale available, the Bureau tests liquid-in-glass thermometers of numerous types at temperatures ranging from −190° to 500° C.; also resistance thermometers, thermocouples, optical and radiation pyrometers to an accuracy demanded for the most precise laboratory instruments. Through the development of special methods and apparatus more than 100,000 clinical thermometers also are tested annually.

Investigations on the temperatures of fixed points have been completed on the freezing-points of palladium, platinum and iridium; and that of rhodium is now under way. To attain the accuracy of 1° or better at the lower temperatures and that of but few degrees at the higher, it was necessary in these investigations to prepare material of extraordinary purity and to provide containers in which it could be melted without contamination. For this latter purpose, thorium oxide, fused by a special technique and molded into crucibles, was used. A necessary additional factor contributing to the successful determination of the freezing-points of metals has been a high frequency induction furnace. In the region of very low temperatures, liquid hydrogen and more recently liquid helium have been used in attaining temperatures below that of liquid air. By fractional distillation of liquid hydrogen, a residue was obtained in which the hydrogen isotope of mass 2 was discovered spectroscopically at Columbia University. Apparatus and methods have recently been developed, in cooperation with the fixed nitrogen research laboratory, for measuring specific heats from the temperature of boiling hydrogen to ordinary temperatures. In the range of liquid helium temperatures, an extensive investigation on superconductivity, especially as affected by the frequency of the current, has been carried on.

In calorimetry, where accurate temperature measurements are of first importance, the Bureau makes available standard heats of combustion in the form of standard samples (pure benzoic acid, naphthalene and sucrose), by means of which the user of a bomb calorimeter may make an accurate calibration of his instrument without a difficult and elaborate primary calibration. Considerable attention has also been given to the more precise definition of heats of combustion, involving the establishment of standard states, and the reduction of results to the basis of these standard states. Investigations of methods of gas calorimetry completed 20 years ago have formed the basis for methods of testing heating value of gas supplies, both by gas companies and regulatory bodies.

The most extensive work in calorimetry carried on by the Bureau has con-



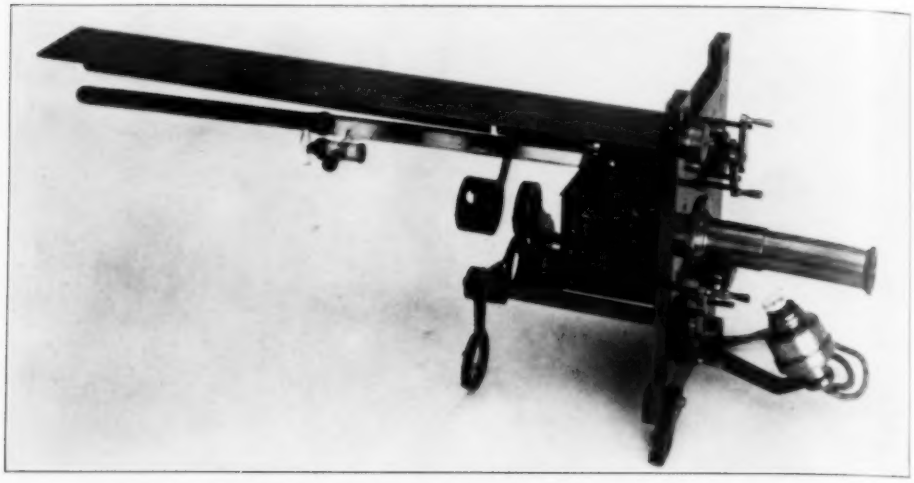
GENERAL VIEW OF LABORATORY EQUIPMENT

DEVELOPED BY THE BUREAU OF STANDARDS FOR MEASURING THE THERMAL PROPERTIES OF SATURATED STEAM. IN THE FOREGROUND IS SEEN THE CALORIMETER DESIGNED FOR OPERATION AT TEMPERATURES UP TO 700° F. (375° C.) AND STEAM PRESSURES UP TO 3,200 POUNDS PER SQUARE INCH. THE PURPOSE OF THE RESEARCH IS TO OBTAIN RELIABLE FUNDAMENTAL DATA ON THE BEHAVIOR OF STEAM FOR THE FORMULATION OF WORKING TABLES.

sisted in determining the thermodynamic properties of materials, such as steam and refrigerating media. This involves the preparation of material of high purity, determination of such properties as the pressure-temperature relation for the saturated vapor, the heat content of the liquid, the latent heat of vaporization, the pressure-temperature-volume relations for the superheated vapor and the specific heat of this vapor. Complete working tables are prepared from these data for the use of engineers in the design and testing of power plant equipment; thus, tables of the properties of ammonia have been issued and have become the standard of the refrigerating industry, both at home and abroad.

Similar work on the properties of steam forms part of an international program designed to provide more reliable data and to cover adequately the higher range of temperatures. The Bureau's measurements, which were preceded by a careful study of the theoretical basis in designing the apparatus, have been completed up to 270° C. (518° F. and 800 lbs./sq. in.). Work above this range is now in progress. Two international conferences, in 1929 and 1931, used the Bureau's results in establishing skeleton tables covering existing knowledge of the properties of steam.

A contribution to the classical problem of determining the mechanical



COBLENTZ THERMOPILE FOR MEASURING RADIATION FROM THE STARS

IT WAS WITH THIS INSTRUMENT THAT THE FIRST SUCCESSFUL MEASUREMENT OF HEAT FROM STARS WAS MADE IN 1914 AT LOWELL OBSERVATORY. IT WAS LATER USED IN A SURVEY OF THE TEMPERATURES OF THE POLAR CAPS, BRIGHT AND DARK AREAS AND CLOUDS OF THE PLANET MARS.

equivalent of heat consists in pointing out that its importance is entirely artificial. Heat is a form of energy and can therefore be measured and expressed in the usual energy units, such as ergs or joules, so that there is no necessity for an independent energy unit, such as the calorie. When this is recognized, the problem of determining the specific heat of water does not differ essentially from the problem of determining the specific heats of other substances.

In the subject of heat transfer, extensive investigations of the thermal conductivity of insulating and building materials and of heat transfer through building walls have provided data from which the insulating value of a wall of specified construction may be calculated; as verified by measurements on representative types of walls. In addition, the conductivities of metals and insulators at high temperatures are being measured. By means of an interferometer and using the refractivity of air as a means of indicating its temperature, it was possible to determine the temperature gradients in the air surrounding a heated body and thus to make a detailed analysis of the manner in which heat was transferred from the heated body to the air.

Another series of investigations has been concerned with the reduction of fire losses in buildings, by testing fire protective materials and construction, in furnaces designed to maintain temperature conditions corresponding to severe fires. The results are expressed in terms of the period of fire exposure during which satisfactory endurance is to be obtained. To make them applicable to existing conditions, the intensity and duration of fires occurring in various classes of building occupancies have been determined by burning experimental buildings and comparing the results with furnace tests. Numerous tests on the types of walls most commonly used have thus made it possible to assign appropriate fire resistance periods to the several types. Similar tests on floors are under way.

As fire is a hazard to life as well as

to property, attention has been given such matters as the provision of adequate exits from buildings, and the protection of audiences by suitable stage curtains. The safe storage of records, the fire protection of government property, the treatment of fabrics and other combustible materials to reduce flammability, means of eliminating causes of fires and related problems have all received attention.

In the subject of power, where the thermal energy from the combustion of fuels is converted into mechanical energy, the Bureau's activity has been centered on the automotive type of engine, the fuels and lubricants required in its use and the vehicles propelled by it. In 1917, the new altitude laboratory, designed for testing aircraft engines under upper air temperature and pressure conditions, signally justified itself by showing that the proposed specifications for aviation gasoline were unnecessarily severe; thereby relieving the country at a critical time of having a condition imposed which would have taxed its resources to the utmost. This laboratory is particularly fitted for studying the effect of: pressure, temperature and humidity of the air, cylinder temperature and oil viscosity on the behavior of aircraft engines.

In 1922, the National Automobile Chamber of Commerce, The American Petroleum Institute and the Bureau entered into a cooperative agreement for the purpose of coordinating the efforts of both the automobile and the petroleum industry to the end that engines might be adapted to use the fuels available and that fuels most suitable for use in engines might be marketed. In this connection, a wide variety of problems, the nature of which has constantly changed with conditions in the industry, has been taken up. When gasoline production was barely sufficient, the problem was to obtain the greatest number of miles per barrel of crude. With the increase in production of crude oil beyond requirements, and cracking processes augmented the supply of gasoline obtainable, increase in mileage has taken a place second to that of increase in satisfaction of operation. For example, the volatility of gasoline should be such as to afford easy starting, yet not lead to boiling in the fuel lines, resulting in vapor lock. Specifications for such a gasoline have been formulated as the result of extensive tests. The knocking tendency of fuels has also been studied and means have been developed for making consistent knock ratings of fuels tested in different laboratories.

THE PROGRESS OF SCIENCE

THE MORRIS ARBORETUM OF THE UNIVERSITY OF PENNSYLVANIA

ONE of the most munificent gifts to the cause of university education in America was made in the will of the late Miss Lydia Thompson Morris, in which she provided that her home in Chestnut Hill, Philadelphia, and her adjacent farming property in Montgomery County should become The Morris Arboretum of the University of Pennsylvania. The home property, "Compton," has long been famous for the beauty of the location and for the very remarkable collection of trees and shrubs planted there chiefly by her deceased brother, Mr. John T. Morris. These plantings occupy more or less completely about 50 acres and are especially rich in specimens from eastern Asia. Miss Morris' will indicated the purpose to which she dedicated this splendid property. The arboretum shall be maintained as a primary object, and the extensions that were being carried out by her are to be continued. The will also provided that a school of graduate botanical research shall be organized and conducted. To aid this purpose, the granting of fellowships is authorized, also the establishment of scholarships for boys and girls studying horticulture and other botanical subjects. The hiring of noted scholars to give lectures, the publication of popular and scientific works, the supporting of botanical researches in this and in foreign lands, the growing of plants for distribution to the interested

THE WALL GARDEN AND THE MANSION

LABORATORY FOR INVESTIGATION OF TREE DISEASES

public and the construction of suitable buildings are among the objects mentioned.

The management and direction of the arboretum is to be conducted through the department of botany of the university. It is directed that the funds of the estate not otherwise provided for should be available for the support of the arboretum and of the projects undertaken by it.

The university became responsible for the initiation of this program last October, and considerable development has taken place. Several hundred new trees and shrubs have been received and placed in the nursery.

The labeling of the plants now in the arboretum has been well advanced, although much critical work still remains to be done. A herbarium record of the plants now present is well begun, representing the plants in bloom, in fruit in many cases, and in winter condition. This herbarium will receive representations from new plants introduced and will offer a wealth of material for the critical botanist.

The arboretum, by participation in the support of Rock's recent expedition on the China-Tibet frontiers, has already received hundreds of kinds of seeds collected by that explorer, among them over 150 Primulas, many of them already germinating in the arboretum greenhouses. Seeds of over 500 collections of Rhododendron are now here.

The buildings at the arboretum are being actively employed. Residences for the superintendent, for the head gardener and for watchmen in different parts of the total area of 160 acres extending along the eastern side of the Wissahickon Creek are in use. The family residence contains an excellently equipped laboratory for the study of diseases of woody plants, in which half a dozen graduate students are at work

ONE OF THE JAPANESE GARDENS

under the direction of Professor Harlan H. York, of the botanical laboratory of the university. Laboratory work is in active operation on problems of mineral plant nutrition by two graduate students. One graduate student working in the mineral constituents of the soil is studying under Associate Professor Edgar T. Wherry. Associate Professor Conway Zirkle is conducting studies in the Bloomfield section on plant genetics. Assistant Professor John Milton Fogg, Jr., is in charge of taxonomic studies on the pines and oaks of the arboretum being carried on by two investigators.

The attic of the garage building has been equipped with an Allison magneto-optical apparatus, which two graduate students are using in studies on the absorption and exchange of mineral constituents of plants under the general direction of Professor True.

Mr. James Lambert, superintendent of the botanic garden of the university, is superintendent of the arboretum, where he is now in residence.

Professor Rodney H. True, of the department of botany and director of the botanic garden of the university, has been appointed director of the arboretum with part-time residence there.

An advisory staff, with members from the school of fine arts, the departments of zoology, chemistry and engineering, has been approved.

Thus, the magnificent gift of Miss Morris opens the door of opportunity for plant studies at the university on a wide basis with financial support to give effect to the program, and promises to make this university and Philadelphia one of the great botanical centers of the country. Should it continue to prosper, it may in time rank with the Royal Gardens of Kew, the Jardin des Plantes in Paris, and the Arnold Arboretum, of Boston, in the world of plant study.

RODNEY H. TRUE

THE HIGH POTENTIAL STATION AT NEW BEDFORD

TEN million volts will soon be available to a group of Massachusetts Institute of Technology physicists. In an airship hangar on Colonel E. H. R. Green's estate at Round Hill, the largest building they could borrow for their experiments, a gigantic electrical machine is being groomed for the study of the effects of high voltages. It consists of two columns surmounted by fifteen-foot hollow aluminum spheres. Men can climb into these hollow metal balls and their interiors will serve as laboratories where the effects of high voltage electricity upon matter can be observed.

The giant electrical machine will provide the world's highest potentials of electricity under human control. Lightning has higher voltage, but man can not effectively harness the lightning.

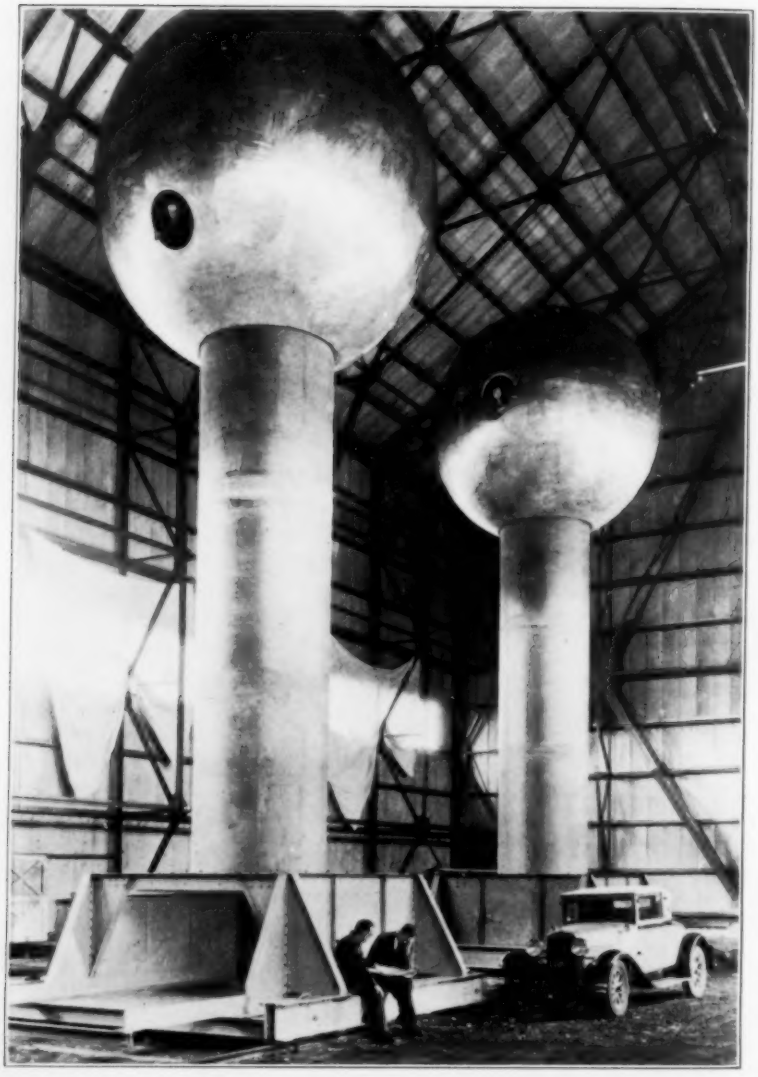
One surprising thing about this ten million volt generator is that it needs no electrical input. It is its own power house. No large transformers are needed. One of the oldest methods of generating electricity is used in this newest high voltage machine. Benjamin Franklin experimented with static machines, and that other great American pioneer in physics, Joseph Henry, used generators of frictional electricity to shock his students who held hands in a circle.

Stroke a cat or comb your hair on a dry day and see the sparks fly. This method of generating static electricity is essentially the same as that in the ten million volt static machine about to be tested in New England. Static electricity antedates the electromagnetic method that is used in the generation of practically all the electric power to-day. The Greeks knew that by rubbing a piece of amber with a cloth an electric charge could be generated. With the practical application of the discoveries of Faraday and Henry, that motion in a magnetic field can generate a current, with the development of the vast electrical industry based upon these principles, static electricity did not have the opportunity of becoming practically useful but remained within the laboratory in the bags of scientific tricks of physics professors.

A modest young man, just thirty-two, is responsible for the application of the principles of static electricity in the development of the electrical machine which will soon give science useful potentials of many millions of volts. Dr. R. J. Van de Graaff was a Rhodes scholar in Oxford when it first occurred to him to use static electricity to obtain high voltage. While in England he did not have the opportunity to make the necessary experiments, but after leaving Oxford he went to Princeton University as a National Research Council fellow. There, with the cooperation of Dr. Karl T. Compton, then professor of physics at Princeton and now president of the Massachusetts Institute of Technology, Dr. Van de Graaff made the first Van de Graaff generator. It cost less than a hundred dollars and it exceeded in voltage developed all the other devices upon which physicists had been working diligently in a half dozen other laboratories.

So striking was the success of the 1,500,000 volt model that Research Corporation funds were obtained under the auspices of the Massachusetts Institute of Technology to build the ten million volt machine which is now about to go into the service of physics.

In principle the Van de Graaff generator is simple. From near the surface of the ground to the elevated hollow cylinders there run moving belts. Electricity is picked up upon these belts at the ground level and it is then conveyed, like water in a bucket pump, to the hollow spheres where it is dumped into them and travels to their surfaces. It is not even necessary to provide a source of low voltage electricity to spray upon the belts as the belts can create and pick up the necessary electricity without aid. One of the hollow cylinders thus has its



THE HIGH POTENTIAL APPARATUS IN THE AIRSHIP HANGAR

surface charged positively and the other is charged with negative electricity. How much electricity the hollow cylinders will hold without spilling over, or sparking like artificial lightning, one from the other, depends upon their size and the atmospheric conditions.

A relatively large amount of electricity, a thousand kilowatts, will be generated by the ten million volt machine when it operates. This is as much as the power plant of a small town generates. Actually the current amounts to 100 milliamperes at a potential of ten million volts.

The generator would light 90,000 ordinary 10 watt, 110 volt incandescent electric lamps, if connected in series, and there would be 10 per cent. current margin to spare. If these lamps were set as close together as possible, say eight to the foot, they would string out to about two miles.

WATSON DAVIS,
Science Service

HISTORICAL MICROSCOPES AT THE NEW YORK BOTANICAL GARDEN

Historical microscopes assembled in what is believed to be the largest collection of its kind in the United States have lately been put on exhibit at the New York Botanical Garden.

Dating from 1740 to the latter part of the nineteenth century, these instruments reveal the progress made from the early, crude, compound microscopes to the nearly perfected achromatic lenses of a century and a half later.

One of the earliest microscopes in the New York Botanical Garden's collection, built by Culpepper in 1740–45.

Despite the imperfections of the earlier models, it was with instruments such as these that the first of the modern botanists—de Jussieu, his nephew Lamont, Linnaeus and later Lamarck—made their studies and discoveries which revolutionized the concept of their subject. Though they used compound microscopes whenever necessary, their vision was continually blurred by the presence of color bands resulting from refracted light rays passing through the lenses. It was many years before achromatism was successfully accomplished. As late as 1821, it was believed impossible to construct a good achromatic microscope, and the single lens was then recommended as the only practical type.

Amici of Florence, one of whose instruments is in the New York Botanical Garden's collection, tried to correct chromatic aberration by a right-angled prism placed immediately above the objective, designed to deflect the light rays through the body-tube.

But this was not wholly successful. A few years later, in 1829, Jackson

W. & S. Jones of London made this microscope, which they described as their "Most Improved Compound Microscope," about 1797. It has a revolving disc of six magnifiers, four objectives, and a large number of accessories.

Lister cemented a plano-concave and a convex lens together with Canada balsam, which is transparent, and thus diminished one half the loss of light from reflection and made the field clearer and brighter. Other improvements fast followed, completely changing the character of the instrument in a subsequent ten-year period. The most important developments in the whole history of the microscope were made during the middle of the nineteenth century. "Little room for improvement can be considered to remain," said one writer at this time.

The microscopes of this changing period, of which there are a number in the botanical garden's collection, were provided with innumerable accessories, including a boxful of prepared slides, showing insects' wings, minute plants and animals, sections of leaves, pollen, microscopic eggs and such objects of fascination for the aided eye. But more important, more exciting, even, to the layman who peered through the tube as a means of entertainment, was the use of the fish-pan, which was part of the equipment. This was a shallow, oblong dish, fitted with clamps or provided with stout twine to hold a small live fish or frog in place. Through the microscope then the wonders of circulating blood could be observed in the fish's tail or the webs of the frog's feet.

"The fact that this collection of microscopes is so rich in the earlier models, which are increasingly difficult to obtain, is an appropriate reason why it should be made a still more comprehensive group," Robert Hagelstein, honorary curator at the New York Botanical Garden, said in issuing a plea for the contribution of additional instruments. The basis of the collection is a gift of twenty microscopes made some years ago by the late Charles F. Cox, when a member of the board of managers.

THREE PEOPLE CAN VIEW THE SAME OBJECT AT THE SAME TIME THROUGH THIS MICROSCOPE, MADE BY NACHET ET FILS, PARIS, SHORTLY AFTER THE MIDDLE OF THE NINETEENTH CENTURY.

C. H. W.

SUMMARY OF THE PRESENT POSITION OF OUR KNOWLEDGE OF ANTERIOR PITUITARY FUNCTION

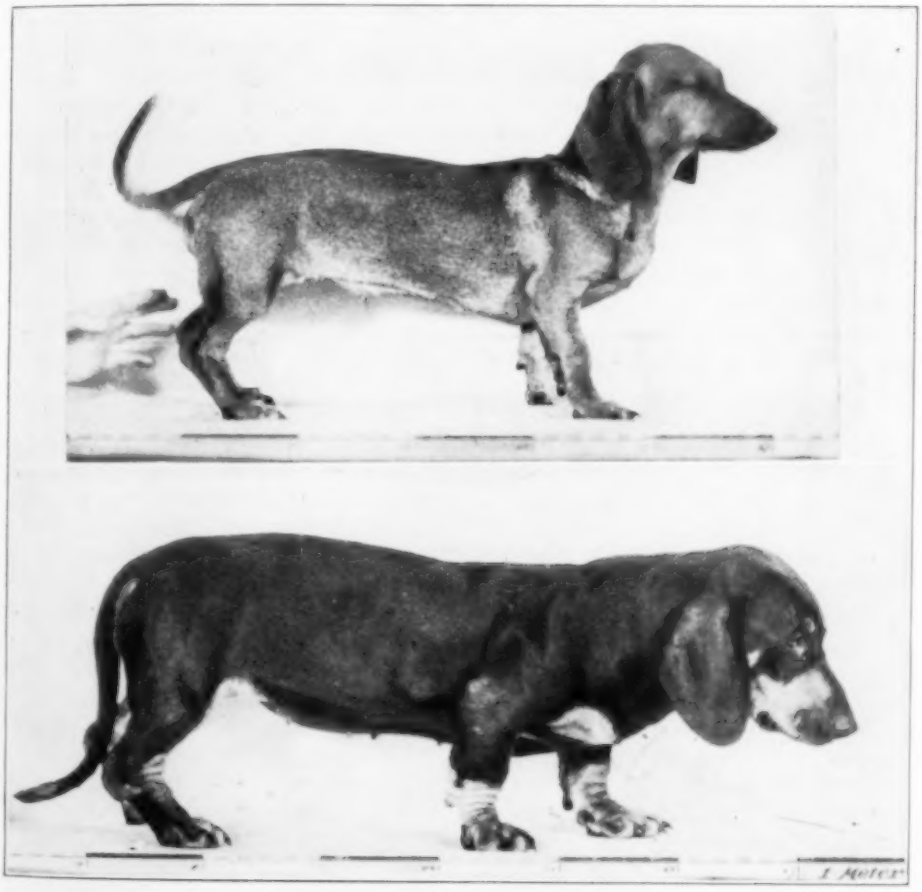
IT is possible that we are at the threshold of a new era in the field of experimental medicine. Dr. Herbert M. Evans, director of the institute of experimental biology at the University of California, who has recently completed a year's work at the Rockefeller Institute for Medical Research, believes that the investigation of the ductless (endocrine) glands probably will yield methods of prevention and control of disease comparable to those developed in the "bacterial epoch" inaugurated by Koch and Pasteur. This subject of endocrinology suffered at its birth from the extravagant assertions of those who claimed to have found in the endocrine glands the long-sought "fountain of youth," or who saw in endocrinology a tool for the lucrative profession of making fat ladies thin. Even so, the investigation of ductless glands has already yielded the greatest single achievement of present-day medicine—the discovery and isolation of insulin.

The hypophysis, or pituitary body, is

a small gland lying at the base of the brain almost in the mathematical center of the head. The Roumanian surgeon, Paulesco, observing that his animals died soon after the removal of the pituitary, concluded the gland was essential for life. This view was held until Harvey Cushing skilfully demonstrated that when the pituitary is removed *without injury to other brain parts*, death need not supervene.

Though the hypophysis was thus shown not essential for continuance of life, it can be demonstrated that complete excision of the gland is followed by progressively more serious ill effects in the body. The triumph of surgery in successfully removing the pituitary without brain injury opened opportunities for test in replacement therapy. By the use of animals deprived of the pituitary we can test gland extracts and determine if we have secured all essential principles of the gland. What are the entities furnished by the pituitary which play so important a rôle in the physiological economy of the animal and which cease to function on complete removal of the gland?

Removal of the pituitary in adult animals first shows little change within the body except for genital retrogression,



EFFECT OF GROWTH HORMONE

CHANGES PRODUCED IN DACHSHUND BY DAILY ADMINISTRATION OF ANTERIOR HYPOPHYSEAL GROWTH HORMONE FOR A PERIOD OF EIGHT MONTHS.

but on removal of the gland or its anterior lobe in young animals there is a cessation of growth characterized by continuance of juvenile structures, such as milk dentition and persistence of epiphyseal cartilages of long bones. Bones may alter in shape, and evidences of disturbed calcium metabolism are indicated. Complete correction of such conditions will occur on injection of a growth hormone from the anterior lobe of the hypophysis into the hypophysectomized animal, in such a way that comparative potencies of growth hormone extracts may be determined and tests for purity made.

A striking effect of removal of the pituitary in the young animal is the failure of the genital system to develop, while in the adult a retrogression occurs with loss of sex interest and desire and ability to produce mature germ cells. Overdosage of pituitary extracts or implantation of the gland tissue in normal immature rats secures a complete sexual maturity.

The hypophysis elaborates a hormone-regulating mammary secretion as well as regulation of sexual maturity, and the experiments of Correr and Riddle will soon establish the fact of a hormone in the pituitary which provokes the secretion of milk.

Removal of the pituitary markedly lowers the metabolic rate of animals in a manner similar to removal of the thyroid. Indeed, the two glands seem dependent on one another in their function and structure, for the thyroid undergoes histological alterations on removal of the pituitary, and injections of anterior pituitary extracts tend to restore metabolic rate and establish normal thyroid structure.

It is found that a principle may be separated by ultrafiltration from the recognized hormones of the pituitary which regulates fat metabolism. The lack of this principle probably is the cause of fat-deposition in animals suffering from hypopituitarism.

Several endocrinologists are now seeking information on relationships between the pituitary and the pancreas. It is found that hypophysectomized animals are more sensitive to insulin, and that implantation of anterior pituitary tissue in diabetic animals will cause a rise in blood sugar content.

Degeneration of adrenal cortex after removal of the pituitary and knowledge of the vital importance of the cortex led to speculation as to whether the death of hypophysectomized animals might not be due to loss of adrenal cortical function. It has been demonstrated, however, that the decline of animals lacking their hypophysis could not be arrested by injection of adrenal cortical hormone, but could be dramatically changed to improvement on administration of anterior pituitary extract, which restores the adrenal cortex to normal also. Very little can now be said regarding a hormone of the pituitary which may aid in replacement therapy in Addison's disease, but accumulating knowledge indicates that hypertrophied fragments of the accessory adrenal tissue may take over the normal function of the adrenals if anterior pituitary tissue is implanted in the body.

One can understand the causes for skepticism with which many look upon the assertions of those who claim to recognize such a perplexing array of apparently discrete internal secretory substances or hormones furnished by the one small brain-gland, the pituitary. Nevertheless, it can be stated with assurance that sufficiently sensitive test objects have been found by means of which at least five principles—growth, gonadotropic, thyreotropic, lactogenic and diabetogenic—may be said to be known with certainty. The effects of these hormones, with perhaps the exception of those for growth, are specific, and we need wait only for more refined biochemical tools before all these substances may be obtained in pure (and preferably crystalline) form.